ELLIPTICAL,
OR
AZIMUTHAL
Horologiography.

Comprehending severall wayes of describing *DIALS* upon all kindes of Superficies either plain or curved: And unto upright Stiles in whatsoever position they shall be placed.

Invented and Demonstrated
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To the READER.

Courteous Reader,

Mongſt other Treatiſes of this deceaſed Author, of which, in their due time, we intend to make thee partaker, we have, in the firſt place, made choice of this, as well in ſome meaſure to keep our word with thee, as alſo to ſtay thy expectation till other things can be made ready. We intend not to ſpend time either in the commendation of It or the Author, being well aſſured that our words will not, where the matter it ſelf is capable to, ſatisfie therein the judicious Reader. Onely let me ſay thus much, that though the generall Subject of this Book is Dialling, yet 'tis handled in a way which no man whoſoever,

that we know of, hath hitherto fully traced. For by it thou wilt ſee, that the repreſenting the true Houre by the ſhadow made by the Axis of the World is but one of thoſe infinite wayes which may be invented, and that it is as poſſible to do the ſame thing by the ſhadow of the Axis of one of the vertical Circles, and by the projection of one Ellipſis upon a plain, ſupply the place of all the Parallels comprehended within the Tropicks. 'Tis true, that Mr. Varnezard, a learned Mathematician, *we think yet living in* France, *hath ſome yeers ſince publiſhed a ſhort Treatiſe in that Language, in which he ſheweth by the projection of an Ellipſis upon the plain of the Horizon, and by the help of an upright moveable ſtile to finde the Houre and Azimuth, with ſome other uſes of the ſame. But this Treatiſe of our Author is very different from that, and moſt of the things here handled, ſuch as are not appliable to his, and in themſelves wholly new.*

In the next place, if it ſhall ſeem ſtrange to any that amongſt other things, as well of this, as of different natures, which we intend ſhortly to Publiſh; we begin firſt with this of Dialling (a Subject upon which ſomething too hath already been publiſhed by our Author, and from whence ſome might perhaps take occaſion to carp at him, as either unable for other things, or too much buſied in this) we deſire them firſt to consider how difficult this Subject hath been thought by the Ancients, and withall what large Volumes have been writ by ſom-

of the beſt rank of later Mathematicians, *(ſuch were* Clavius, Maigran, *and others) and then compare their wayes with what they ſhall here and hereafter (God willing) finde in our Author, and we doubt not, but they will be forced to yield him this honour, to have made that* Art, *in all the Caſes of it, and all Circumſtances thereunto belonging, more eaſie and expedite both in the Underſtanding and Practice, and with much more brevity than any that have gone before him either of our own or other Nations.*

Laſtly, we advertize thee (Reader) *that our Authour, in regard of his great and long infirmities, could not fit either this, or any other of his Treatiſes for the Preſſe, as he deſired and intended; and therefore they muſt needs want much of that accompliſhment which otherwiſe they would have had. But we hope, notwithſtanding, thou wilt finde ſo much of worth in them as they now are, whereby thou wilt judge them (as we do) fitter to be made publick, then wholly ſuppreſſed.*

John Twyſden,
Edmund Wingate.

ERRATA.

Page 85. line 11. for *Pag.* 81. read *Pag.* 70. There are divers other literall faults, but this is moſt materiall.

ELLIPTICAL
OR
AZIMVTHAL
Horologiography.

Of the Elliptical Dial, *whose Index ſtands perpendicular to the plain: How to draw and divide the Ellipſis upon an Horizontal plain, or any other plain that declineth not.*

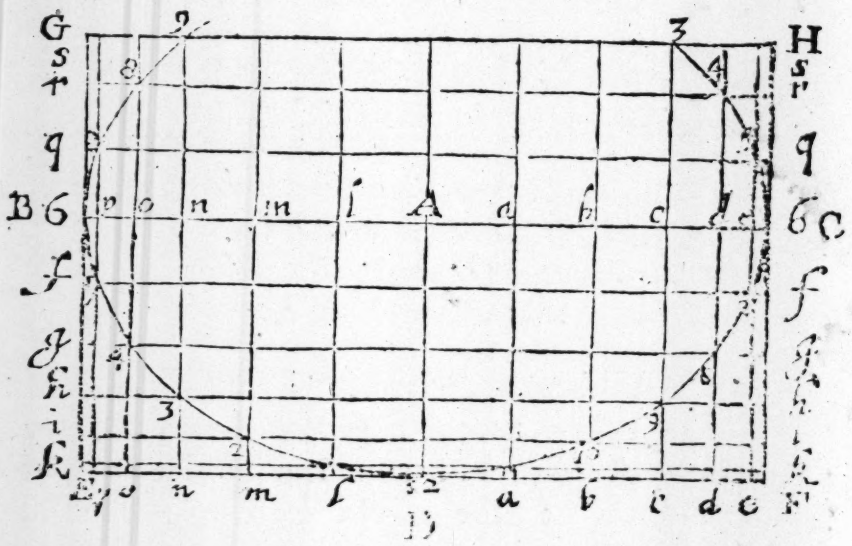
1. LEt the two right lines B C and A D, cut each other at right angles in A. Then making A C or A B as a Radius, let A D be the Right Sine of the Poles elevation above the plain; and make up the Rectangled Parallelogram B E F C, and continue it further to G and H.

2. Divide the Radius A C into the Sines of 15, 30, 45, 60, 75 *gr.* at *a b c d e*, which ſtand for the ſix equall houres: ſo that A *a* may be the Sine of one houre, A *b* of two houres, A *c* of three houres, A *d*, A *e* of four and five houres. And

in the ſame ſort divide the other lines which are equall to A C, namely D F, A B, D E, into the ſame parts, at *a b c d e*, and at *l m n o p*: and draw the parallel lines *a a*, *b b*, *&c. l l*, *m m*, *&c.*

Then taking A D, or C F, or B E, for a Radius, ſet on again the Sines of the ſix equall houres from B and C, at *f g h i k*, and as many as ſhall be needfull on the other ſide, at *q r s*: and draw the parallel lines *f f*, *g g*, *&c.* and *q q*, *r r*, *&c.*

Theſe lines thus croſſing one another will make ſmall Parallelograms, which will ſhew both where the Ellipſis is to be drawn, and where to be divided. For,



3. Firſt, If a curved line be begun at D or 12, and carried both wayes diagonally through the ſucceeding Parallelograms, the ſame line ſhall be the Ellipſis required. Thus you ſee it carried from D to 11, from 11 to 10, from 10 to

to 9, and ſo through the ſucceſſive oppoſite angles of the following Parallelograms, at 8, 7, 6, 5, 4, 3. And on the other ſide in the ſame manner, from D, diagonally through 1, 2, 3, 4, 5, 6, 7, 8, 9. This line thus regularly deſcribed without angles, and extravagant inordinate flexures, is the Ellipſis here intended.

Secondly, If from the center A, through each of the angular points in the ſmall Parallelograms, certain ſhort lines be drawn, (as in the figure you ſee done at 11, 10, 9, *&c.* and at 1, 2, 3, *&c.*) the ſame lines ſhall be the requiſite horary diviſions of the Elliptical line.

4. If theſe diviſions into ſingle houres ſhall not be enough, but that more exactneſſe is required, into halves and quarters; then muſt you (beſides the Sines of whole houres at *a*, *b*, *&c.* *l*, *m*, *&c.*) put in the right Sines of the intermediate halves and quarters of the equall houres; which will be eaſie to do by the former directions.

Declinations of the Sun

	Janu.		*Febru.*		*March*		*Aprill*		*May*		*June*	
1	21	49	13	57	3	34	8	30	18	01	23	11
2	21	39	13	37	3	11	8	52	18	16	23	14
3	21	29	13	17	2	47	9	13	18	31	23	18
4	21	18	12	57	2	23	9	34	18	46	23	21
5	21	07	12	36	2	00	9	56	19	00	23	24
6	20	56	12	15	1	36	10	17	19	14	23	26
7	20	44	11	54	1	12	10	38	19	27	23	28
8	20	32	11	33	0	48	10	59	19	40	23	29
9	20	19	11	12	0	24	11	20	19	53	23	30
10	20	06	10	50	Æquin.		11	40	20	06	23	31
11	19	53	10	28	0	24	12	01	20	18	23	31
12	19	39	10	06	0	48	12	22	20	30	23	31
13	19	25	9	44	1	12	12	42	20	42	23	31
14	19	10	9	22	1	36	13	02	20	53	23	30
15	18	55	9	00	2	00	13	21	21	04	23	28
16	18	40	8	38	2	23	13	40	21	14	23	26
17	18	25	8	15	2	47	14	00	21	24	23	24
18	18	10	7	52	3	11	14	19	21	34	23	20
19	17	54	7	29	3	34	14	38	21	43	23	17
20	17	37	7	06	3	57	14	57	21	52	23	14
21	17	20	6	43	4	20	15	15	22	01	23	11
22	17	03	6	20	4	43	15	32	22	10	23	06
23	16	46	5	57	5	06	15	49	22	18	23	01
24	16	28	5	34	5	29	16	06	22	25	22	56
25	16	10	5	11	5	52	16	23	22	32	22	51
26	15	52	4	47	6	15	16	40	22	39	22	45
27	15	34	4	24	6	38	16	57	22	45	22	39
28	15	15	4	01	7	00	17	13	22	51	22	32
29	14	56			7	22	17	29	22	57	22	25
30	14	37			7	45	17	45	23	02	22	17
31	14	17			8	08			23	07		

——from the Æquinoctiall.

	July		Augu.		Septẽ.		Octob.		Novẽ.		Decẽb.	
1	22	09	15	15	4	29	7	10	17	36	23	07
2	22	00	14	57	4	06	7	33	17	52	23	12
3	21	51	14	39	3	43	7	56	18	08	23	16
4	21	42	14	21	3	20	8	18	18	24	23	19
5	21	33	14	02	2	57	8	40	18	40	23	22
6	21	23	13	43	2	34	9	02	18	55	23	25
7	21	13	13	24	2	10	9	24	19	10	23	27
8	21	02	13	05	1	47	9	46	19	24	23	29
9	20	51	12	45	1	24	10	08	19	38	23	30
10	20	40	12	25	1	00	10	30	19	52	23	31
11	20	29	12	05	0	37	10	51	20	05	23	31
12	20	17	11	45	Æqui	14	11	12	20	18	23	31
13	20	05	11	25	noct.	10	11	33	20	31	23	31
14	19	53	11	04	0	34	11	54	20	43	23	30
15	19	40	10	43	0	58	12	15	20	55	23	28
16	19	27	10	22	1	22	12	36	21	06	23	25
17	19	13	10	01	1	46	12	57	21	17	23	22
18	18	59	9	40	2	10	13	17	21	27	23	19
19	18	45	9	19	2	33	13	37	21	37	23	16
20	18	30	8	58	2	56	13	57	21	47	23	12
21	18	15	8	36	3	19	14	16	21	57	23	08
22	18	00	8	14	3	42	14	35	22	06	23	03
23	17	45	7	52	4	06	14	54	22	15	22	58
24	17	30	7	30	4	29	15	13	22	23	22	52
25	17	14	7	08	4	52	15	32	22	32	22	45
26	16	58	6	46	5	15	15	51	22	38	22	38
27	16	42	6	24	5	38	16	09	22	45	22	31
28	16	25	6	01	6	01	16	27	22	51	22	24
29	16	08	5	38	6	24	16	45	22	57	22	16
30	15	51	5	15	6	47	17	02	23	02	22	08
31	15	33	4	52			17	19			21	59

Tangents of the Suns decli——

	Janu.	*Febru.*	*March*	*April*	*May*	*June*
1	4005	2484	0623	1498	3251	4281
2	3971	2422	0554	1562	3300	4295
3	3936	2360	0485	1626	3348	4307
4	3900	2297	0416	1690	3396	4317
5	3863	2234	0347	1754	3443	4326
6	3825	2170	0278	1818	3489	4334
7	3785	2106	0209	1881	3534	4341
8	3744	2042	0140	1944	3576	4347
9	3702	1978	0070	2007	3618	4350
10	3659	1913	Æquin.	2069	3659	4351
11	3615	1847	0070	2131	3700	4352
12	3570	1781	0140	2193	3740	4352
13	3524	1715	0209	2254	3779	4351
14	2477	1649	0278	2315	3817	4348
15	3429	1582	0347	2375	3854	4343
16	3380	1515	0416	2434	3889	4336
17	3330	1448	0485	2493	3922	4327
18	3280	1381	0554	2552	3952	4317
19	3230	1314	0623	2610	3982	4306
20	3177	1246	0692	2668	4012	4294
21	3123	1178	0761	2725	4042	4281
22	3068	1110	0829	2780	4071	4266
23	3013	1042	0897	2834	4099	4250
24	2957	0974	0965	2888	4125	4232
25	2900	0906	1033	2941	4149	4213
26	2842	0837	1101	2994	4171	4193
27	2784	0768	1168	3047	4192	4172
28	2726	0699	1235	3099	4212	4149
29	2667		1301	3150	4231	4124
30	2607		1367	5201	4249	4098
31	2546		1433		4266	

———nation from the Æquinoctiall.

	July	*Augu.*	*Septẽ.*	*Octob.*	*Novẽ.*	*Decẽb.*
1	4071	2727	0784	1257	3170	4272
2	4042	2671	0717	1325	3222	4287
3	4012	2615	0650	1392	3275	4300
4	3981	2558	0584	1458	3326	4311
5	3949	3500	0517	1524	3377	4321
6	3916	2442	0450	1590	3427	4330
7	3882	2383	0383	1656	3476	4338
8	3847	2323	0316	1722	3523	4345
9	3811	2263	0249	1788	3568	4350
10	3776	2202	0181	1853	3613	4352
11	3739	2141	0112	1917	3657	4352
12	3700	2079	Æq 42	1981	3700	4351
13	3660	2017	uin. 29	2045	3742	4350
14	3618	1955	0099	2109	3782	4347
15	3575	1893	0169	2172	3821	4341
16	3532	1831	0239	2235	3859	4333
17	3487	1768	0309	2298	3896	4324
18	3442	1705	0378	2360	3932	4314
19	3396	1642	0446	2422	3967	4302
20	3349	1578	0514	2483	4000	4288
21	3301	1513	0582	2543	4031	4273
22	3253	1448	0650	2603	4061	4256
23	3204	1382	0718	2662	4090	4238
24	3154	1316	0786	2721	4118	4217
25	3103	1250	0854	2779	4146	4195
26	3052	1184	0921	2837	4172	4172
27	3000	1118	0988	2895	4196	4148
28	2947	1052	1055	2952	4218	4123
29	2893	0985	1122	3008	4238	4096
30	2838	0918	1189	3063	4256	4068
31	2783	0851		3117		4038

SECT. I.

Of the Elliptical Dial, *where the Index ſtands perpendicular to the Plain: How to draw it for an* Horizontal *Plain, or any other Plain that declineth not.*

BEcauſe here is no declination ſuppoſed, therefore the draught will be the more eaſie.

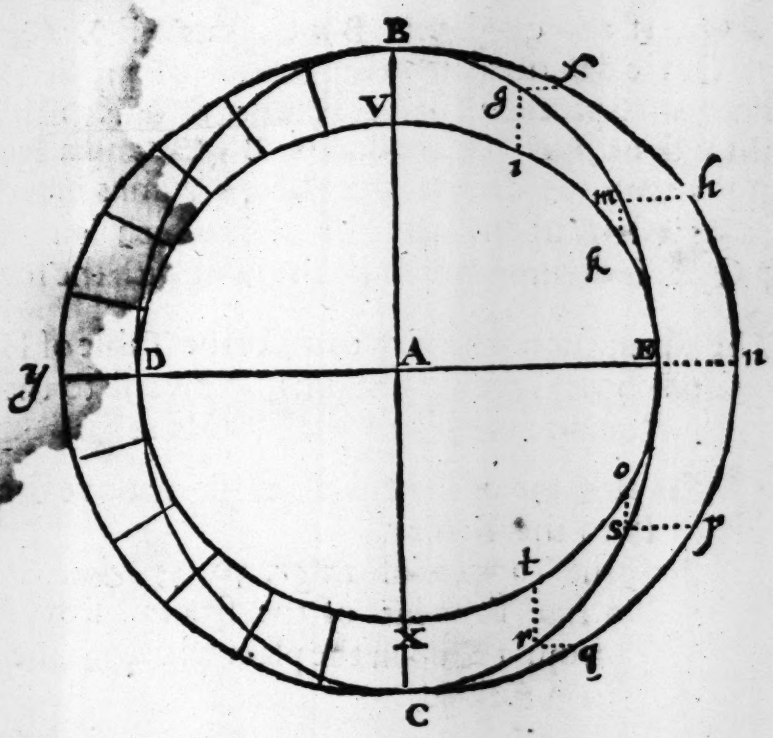
1. Make B C for the longer Diameter of your Ellipſis, aud count one halfe of it, that is A B or A C as the Radius, and through the point A, draw an infinite line (as D E) at right angles to B C. Then for the ſhorter Diameter, you muſt conſider the elevation of the Pole above your plain. Looke therefore to make A D or A E equall to the Sine of the Poles elevation, which Sine muſt be eſtimated to the Radius A B. Thus you have the two extream diameters.

2. Through the four points D B E C you may deſcribe the Ellipſis, either by Elliptical Compaſſes, or by finding many points through which it is to paſſe: for effecting which there are multitudes of wayes preſcribed.

One may be this. Deſcribe two Circles upon the two extream Diameters B C and D E. Divide them both into any like parts, as B *f h n p q* C, and V *i k* E *o t* X; and from each couple of thoſe like diviſions (as *f* and *i*) draw *f g i g*, (the firſt parallel to A *n*, the ſecond parallel to A B) cutting each other at right angles in *g*, ſo the point *g* ſhall be one of the points through which the Ellipſis is to be deſcribed. In the ſame manner, from *h* and *k* muſt be drawn

two

two lines concurring at right angles in *m*, which will [illegible] fore be another point through which the Ellipsis must passe. So again from *p* and *o*, *s* and *q*, lines are to be drawn, concurring at right angles in *s* and *r*, which are two other points of passage for the Ellipsis. After this manner may the other halfe B D C be described.



How to divide the Ellipsis into its requisite parts.

1. If the parts B *f h n p q* C were all equall, and 12 of them in number, then would the points *g m*, &c. be the houre points. And accordingly, if those houres were subdivided into equall halves and quarters, &c. there would be found points for the halves and quarters, &c. of the houres.

And if the Ellipsis be first drawn, then the exteriour Circle it selfe by lines issuing out of *f h p q*, drawn parallel to A *n*) will divide the Ellipsis: or, where these lines cut it more obliquely (as at *g* and *r*, *&c.*) there the lesser Circles equall parts (at *i* and *t*, *&c.*) will cut the same Ellipsis at more right angles, so that one of them may help the other in this division.

2. Or, If the quadrants B *n* C, or V E X (or of any other Circle described upon the center A) were divided into Horizontall Spaces, such as are proper for this Diall (as you see them done upon the quadrants B *y* C) and a Ruler laid from the center A did transfer those divisions into the Ellipsis (as is done upon that halfe of it which is noted with B D C) this division would be the same with the former.

The proportion whereby to make the Table of Horizontall Spaces for this Ellipsis, is inverse to that which is for common Horizontall Dials: thus,

As the Sine of the Poles elevation above the plain,
Is to the Radius;
So is the Tangent of 15 *gr.* 30, 45, *&c.*
To the Tangent of the spaces of every houre from 12, upon the plain whereon the Ellipsis is described.

And according to these spaces must every houre be set on from *n* or *y* towards B or C.

How to make the Zodiac, or dayes of the yeare, whereby the Ellipsis and Index are to be set in a right position, that they may daily stand true to shew the houre.

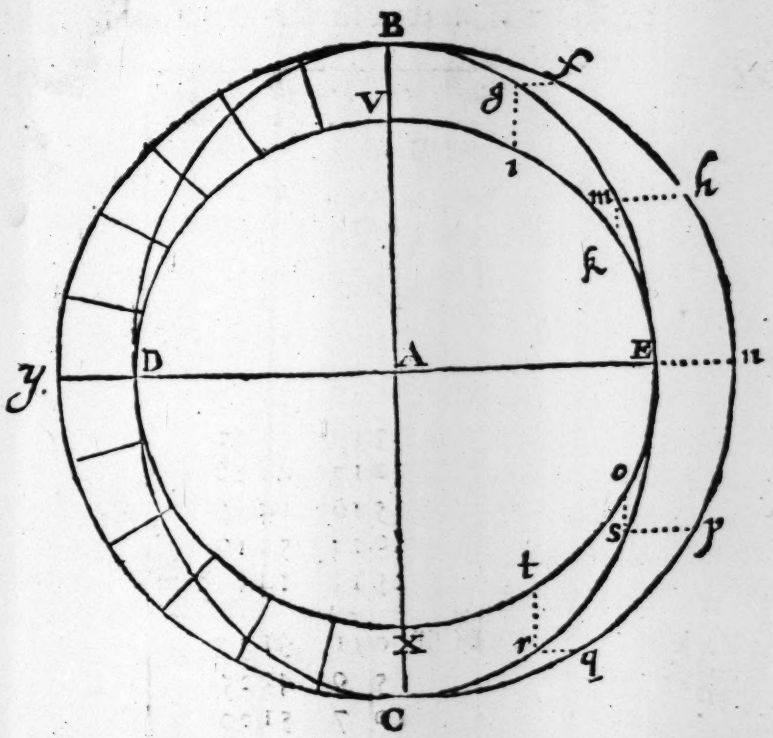
Whether the 12 Signes or the 12 Moneths be fittest for

use

uſe, is left to every mans choiſe. But in both theſe it is required that the declinations due to the Signes or Dayes be known, becauſe theſe are to be inſcribed by them. So that now it only remains to be ſhewed what kinde of Scale that muſt be, out of which the foreſaid Declinations are to be taken.

In generall, the Scale muſt be a Scale of Naturall Tangents.

In particular, there are theſe two Rules, one of which will with due convenience ſerve for all kindes of Latitudes, or elevations. You may uſe which is moſt ſutable to your purpoſe.



The firſt for great Latitudes. Make the leſſer ſemidiameter A D or A E, to be a Tangent of the Poles elevation

above the plain; and that Scale is the Scale of Tangents out of which the Declinations (before mentioned) must be taken.

The second for lesser **Latitudes.** To the Radius B A, finde the Co-sine of the plains latitude or elevation; and make that Co-sine a Radius, or Tangent of 45 *gr.* and this will be the same Scale with the former.

By these wayes the Declinations of these two Tables (one for the Signes, the other for the Dayes of the Moneths) may be inserted from the Equinoctiall line, or middle of the Scale, by the graduations of such a Tangent line as is before mentioned.

Signes.	*Declin.*		*Signes.*
♈ ♉ 0	23	31	30
5	23	26	25
10	23	9	20
15	22	41	15
20	22	2	10
25	21	12	5 ♊
♌ ♍ 0	20	13	30
5	19	5	25
10	17	48	20
15	16	24	15
20	14	52	10
25	13	14	5 ♎
♑ ♐ 0	11	31	30
5	9	43	25
10	7	51	20
15	5	56	15
20	3	58	10
25	2	00	5 ♓

Moneths.

Moneth	Declin.		Moneth	Declin.		Moneth	Declin.		Moneth	Declin.	
Jann. 5	21	7	April 5	9	56	July 5	21	33	Octob. 5	8	40
10	20	6	10	11	41	10	20	41	10	10	29
15	18	55	15	13	20	15	19	39	15	12	15
20	17	37	20	14	55	20	18	30	20	13	56
25	16	10	25	16	23	25	17	14	25	15	32
31	14	17	30	17	45	31	15	33	31	17	18
Febr. 5	12	36	May 5	19	0	Aug. 5	14	1	Nove. 5	18	40
10	10	50	10	20	6	10	12	24	10	19	51
15	9	00	15	21	4	15	10	42	15	20	54
20	7	6	20	21	53	20	8	56	20	21	47
25	5	11	25	22	32	25	7	7	25	22	30
28	4	1	31	23	6	31	4	52	30	23	2
Mar. 5	2	0	June 5	23	24	Septe. 5	2	56	Dece. 5	23	22
10	Æ	1	10	23	31	10	1	0	10	23	31
15	2	0	15	23	28	15	Æ	57	15	23	28
20	3	57	20	23	14	20	2	55	20	23	11
25	5	52	25	22	50	25	4	51	25	22	45
31	8	7	30	22	17	30	6	46	31	21	58

Or if it be required rather to ſet them on by a Decimal Scale equally divided, then muſt the Tangents of theſe Declinations (here ſpecified) be uſed, and the Decimal Scale muſt be equal to the Co-ſine of the plains Latitude, which Co-ſine muſt be limited to B A, the greater Radius of the Ellipſis. And for this purpoſe here are two Tables more which do expreſſe the ſaid Tangents.

Signes

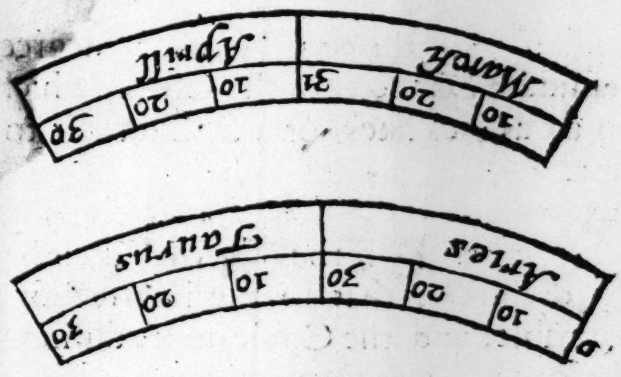
Signes.	*Tang*	*Signes.*	*Moneth*	*Tang*	*Moneth*	*Tang*	*Moneth*	*Tang*	*Moneth*	*Tang*
♑ ♋ 0	4348	30	*Janu.*	2862	*Aprill* 5	1751	*July* 5	3949	*Octob.* 5	1524
5	4334	25	10	3659	10	2068	10	3775	10	1850
10	4276	20	15	3427	15	2370	15	3571	15	2171
15	4180	15	20	3175	20	2664	20	3346	20	2481
20	4047	10	25	2899	25	2940	25	3102	25	2780
25	3879	5 ♊	31	2546	30	3201	31	2783	31	3115
♒ ♌ 0	3683	30	*Febr.* 5	2235	*May* 5	3443	*Ang.* 5	2496	*Nove.* 5	3378
5	3460	25	10	1914	10	3659	10	2199	10	3610
10	3211	20	15	1584	15	3852	15	1890	15	3819
15	2943	15	20	1246	20	4017	20	1572	20	3996
20	2655	10	25	0907	25	4149	25	1249	25	4142
25	2352	5 ♉ ♍	28	0702	31	4265	31	0851	30	4252
♓ ♍ 0	2038	30	*Mar.* 5	0349	*June* 5	4327	*Septe.* 5	0512	*Dece.* 5	4320
5	1712	25	10	Æq 3	10	4348	10	0175	10	4348
10	1379	20	15	0349	15	4341	15	♐166	15	4341
15	1039	15	20	0690	20	4293	20	0509	20	4283
20	0693	10	25	1028	25	4210	25	0849	25	4193
25	0349	5 ♈ ♎	31	1426	30	4098	30	1187	31	4033

Another way to describe and divide the same Zodiac, or Scale of Moneths.

The former descriptions do suppose that the yearly course of the Sun is to be set in a streight Scale, in which the parts neerest to the two Tropicks will be exceeding close together; and those at the Æquinoctiall or middle part of the Scale will be wide. But if it shall better be liked that the parts should stand distinctly one from the other; it will then be most expedient, First, to limit out the whole length of the Scale: then upon that length (as a diameter) to describe a Circle, and to divide it as is here under shewed.

How to divide the Annuall Circle into its requisite parts.

You are first to divide the Circle (it selfe, or one equall to it) into 360 equall degrees, and by them to divide the said Circle into such unequall parts as the numbers of degrees and minutes expressed in the Tables will require. The two Tables are the Right Ascensions of such parts of the Ecliptic as are due to the Suns place or Declination, in any of the Signes, or of any dayes of the 12 moneths. The Tables are here placed. The manner of dividing the Circle is the same with other like things of this kinde.



Mon	R. Ascen.	Mon	R. Ascē	Mon	R. Ascen	Mon	R. Ascen.
Ja 10	302 43	A 10	28 36	♑ 10	119 47	O. 10	205 06
20	313 16	20	37 56	20	129 40	20	214 53
31	324 21	30	47 33	31	140 15	31	225 50
Fe 10	334 03	M 10	57 23	A 10	149 37	N 10	236 11
20	343 30	20	67 27	20	158 48	20	246 51
28	351 07	31	78 45	31	168 45	30	257 57
M 10	0 14	♑ 10	89 05	S. 10	177 44	D 10	269 02
20	9 18	20	99 27	20	186 47	20	280 11
31	19 19	30	109 43	30	195 53	31	292 08

Signs	*R. Aſcē*		*Signs*	*R. Aſcen.*		*Signs*	*R. Aſcen*		*Signs*	*R. Aſcen.*	
♈ 10	9	11	♉ 10	100	53	♎ 10	189	11	♑ 10	280	53
20	18	27	20	111	39	20	198	27	20	291	39
30	27	54	30	122	12	30	207	54	30	302	12
♉ 10	37	34	♌ 10	132	28	♏ 10	217	34	♒ 10	312	28
20	47	32	20	142	26	20	227	32	20	322	26
30	57	48	30	152	06	30	237	48	30	332	06
♊ 10	68	21	♍ 10	161	33	♐ 10	248	21	♓ 10	341	33
20	79	07	20	170	49	20	259	07	20	350	49
30	90	00	30	180	00	30	270	00	30	360	00

The beginning of the equall parts or degrees, muſt be upon that middle Diameter of the Circle, which lies parallel to the two ſix a clock lines, or perpendicular to the twelve a clock line.

The beſt manner of dividing the Circle is as in the preceding figure, eſpecially if the fiduciall Circle be cut through with ſmall diviſions, that ſo the interſections may be the more diſcernable, and the Circle more diſtinguiſhable from the reſt; and more cleere from miſtakes.

Concerning the Index.

The Index muſt ſtand perpendicular to the plain, and muſt, according to the time of the year, be neerer or further from the Ellipſis.

Now, Whether the Index ſhould move upon the plate lying ſtill, or the elliptical plate move towards the Index fixed upon another plate, muſt be left to every mans judgement and beſt liking. But the mover with its peculiar Index (called

(called here the Zodiacall Index) must move according to the length of the plains Meridian line, either in it, or parallel to it, alwayes so that the fiduciall edge of the Dials Index may ever stand in the Meridian line.

But if to this Ellipticall Diall it be thought fit to joyn an ordinary Horizontal Dial (fitted to the Elevation of the Pole above the plain) that so it may set it selfe true North and South, which by this double kinde of Diall it will do; for the houres in both Dials will never agree to be the same till it stand right, and the best time for setting it, is when the Sun is in the East or West Azimuth, the worst time is at Noon: then the common Horizontal Dial may be the standing plate, the Index of the Ellipsis being fixed to it, the elliptical plate may move too and fro upon the horizontal fixed plate, according to the graduations of the Zodiac.

Of the place for the Suns Annual course or Zodiac.

Whichsoever of the two (the Ellipsis or Index) is moveable or fixed, it matters not. In both wayes it is necessary to set the Zodiac right, which must thus be done.

Let the fiduciall edge of the Index be placed exactly in the center of the Ellipsis. And being there set, let the place of the line or threed (or whatever it be that serves for the Zodiacall Index) be marked upon the standing plate. Then through that mark or point draw a streight line parallel to the line of the two sixes, or perpendicular to the line of twelve. The same line is to be esteemed for the Æquinoctiall: and from thence are all the parts of the Scale (or Circle) to be inscribed by help of the former Tables.

The Uſes of the Elliptical Dial.

The Index and Ellipſis being uſed alone, and ſet to their true diſtance, by the help of the Zodiac, the Ellipſis it ſelfe with its upright Index, will ſhew the true houre of the day.

But it is ſuppoſed hitherto, that the plain be either direct, looking full North or South, or elſe Horizontal: and in every ſuch plain, there muſt be drawn the Meridian line of the place or plain, which in direct flats are one and the ſame. And according to the Coaſt of this Meridian line muſt the moving or ſliding be, as alſo the line of 12 upon the Ellipſis muſt lie in or parallel to it.

This way therefore requires, firſt, a Meridian line to be drawn, whereby to place the Ellipſis. And in all direct plains the Meridian line is the ſame with the Vertical line of the plain.

But if to this Elliptical Dial, be adjoyned a common Horizontal Dial with an Axis, then there needs no finding of a Meridian line before hand, becauſe they two betwixt them will finde one, and conſequently will place themſelves in a true poſition. Only with this *proviſo*, that if the plain be not Horizontal, it muſt yet be ſuch as looketh directly North or South. This was intimated before.

There may other uſes be made of it, if it have other Scales adjoyned to the Zodiac.

1. If a Tangent line of $23\frac{1}{2}$ *gr.* be inſcribed according to the length of the Zodiac, then when the ſituation of the Ellipſis to the Index is fitted, the Zodiacal Index will ſhew

(upon

(upon this Tangent Scale) the Suns Declination.

2. In the 11 page there are two Rules given whereby to finde that Scale of Tangents out of which the Zodiacal Scale is to be divided. If then out of that Scale of Tangents so found and limited, you take the Co-tangent of your Latitude, and divide that length as a Radius or whole line of Sines into houres and parts of houres, and put in so many of them as will reach the Suns greatest Declination, or the length of the Zodiac both wayes from the Equinoctiall; then the former rectification of the Zodiacal Index to the day of the moneth or Suns place, will perfectly shew (in this Scale, and for that Latitude to which all the work is made) the Ascensional difference, with what depends thereon: namely, the length of the Day and Night, and the time of Sun Rising and Setting.

3. The Dial being fixed in a true position, the Place or Coast of the Sun rising and setting upon the plain, may be discerned in the heavens. For when the Ellipsis is rectified, and the time of the Sun rising or setting is known (as before) then with your eye project the fiduciall edge of the upright Index upon that time of Sun rising or setting counted in the Ellipsis, and the same edge will shew in the heavens whereabout the Sun will ascend or descend upon the plain. That is, it shews the Amplitude of Sun rising upon the plain.

1. Note, That if the plain be Horizontall, then the two last Uses serve for the place where a man lives. But if the plain be not Horizontal, then it serves not for the place, but is proper to the plain it selfe, or to that Horizon or Latitude which the plain represents, according as they are set down in the former Rules: because things are done to the plains Latitude, and not to the places.

2. Note again, that if upon plains that are not Horizontal, you would yet have them (to ſhew the ſecond of theſe laſt preceding concluſions, namely,) to ſhew the time of Sun riſing or ſetting for the place in which you are, and not for the plains, then muſt you take (not the Co-tangent of the plains Latitude, but) the Co-tangent of the Latitude of the place, juſt as you did in the Horizontall plain, and then the Zodiacal Index being rectified will effect the thing required for the place, and not for the plain.

3. Note, that both in the Horizontal and the other plains, there may be a peculiar Scale put, either for the Amplitude proper to thoſe plains, or elſe for the Amplitude proper to the place, if a Table of Amplitudes be computed for either of them, by this proportion.

As the Radius,
to the Sine of 1, 2, 3, *&c.* or 5, 10, 15, *&c.* degr. of Amplitude;
So the Co-ſine of the poles elevation,
To the Sine of the competent declination:

And then by the ſaid competent declination (taken in the Scale of Tangents of $23\frac{1}{2}$ equal to the halfe Zodiac) the forenamed Amplitudes be inſcribed. Or having the Declinations, you may look out their Tangents in the Canon, by which Tangents the ſaid Amplitudes may be inſerted with help of the Decimall Scale made to the Co-ſine of the plains Latitude, as was before mentioned.

The Amplitudes proper to the plain are of no great uſe, unleſſe

unleſſe the plain do juſtly repreſent the Horizon of ſome known place, whoſe Amplitude you deſire to be acquainted withall. I have therefore here added a particular Table belonging to the Latitude of *London* 51 *gr.* 30 *min.* that by it the ſaid Amplitudes may be inſerted into ſuch direct Recliners and Incliners as ſhall any way ſtand in the ſaid Latitude.

A Table of Amplitudes, *with their anſwerable Declinations, for the Latitude of 51 gr. 30 min.*

A.	Declin		A.	Declin.		A.	Declin.		A.	Declin	
1	0	37	11	6	43	21	12	53	31	18	42
2	1	14	12	7	26	22	13	29	32	19	16
3	1	52	13	8	03	23	14	04	33	19	49
4	2	29	14	8	40	24	14	40	34	20	22
5	3	07	15	9	16	25	15	15	35	20	55
6	3	44	16	9	53	26	15	50	36	21	28
7	4	21	17	10	29	27	16	25	37	22	00
8	4	58	18	11	05	28	17	00	38	22	32
9	5	36	19	11	41	29	17	34	39	23	04
10	6	12	20	12	18	30	18	08	40	23	35

Another Table of Amplitudes, *with the Tangents of their anſwerable Declinations, for the Latitude of 51 gr. 30 mi.*

A.	Tan.	A.	Tan.	A.	Tan.	A.	Tan.
1	0109	11	1196	21	2289	31	3385
2	0217	12	1305	22	2398	32	3495
3	0326	13	1414	23	2507	33	3604
4	0434	14	1524	24	2617	34	3712
5	0543	15	1632	25	2726	35	3822
6	0652	16	1741	26	2836	36	3932
7	0761	17	1851	27	2946	37	4040
8	0869	18	1960	28	3056	38	4149
9	0981	19	2069	29	3166	39	4258
10	1087	20	2180	30	3275	40	4365

So

So far of this Elliptical Dial, as it is to be deſcribed upon any direct plain which lies under the ſame Meridian with the Meridian of the place, and which declineth not from it.

SECT. II.

How to frame the Elliptical Dial *to other Plains which are not direct but declining: To an Index that ſtandeth perpendicular to the plain.*

IT is not here to be enquired whether the plain declining, be erect or leaning; for one rule ſerves both theſe kindes. But then it muſt firſt be ſuppoſed, that the plains ſituation is in all reſpects known, how much and which way it declines and reclines or inclines.

Secondly, Theſe three things muſt further be found (either by calculation or otherwiſe) namely,

1. *The Poles elevation above the plain.*
2. *The plains difference of Longitude.*
3. *The departure of the ſubſtylar (which is the plains proper Meridian) from the Vertical line of the plain.*

Theſe are pre-requiſites to that which comes after, in which you muſt proceed by the following directions.

How

How to limit and draw the Ellipſis.

Having the ſubſtylar or proper Meridian drawn upon the plain, in its true poſition, and alſo knowing the elevation of the Pole above the plain, you may, upon the ſubſtylar line, ſet out your ſhorter diameter, and on a line drawn perpendicular thereto, you may ſet off the longer diameter, in this proportion: Let the longer Diameter be as the Radius, the ſhorter as the Sine of the plains Latitude taken to the ſame Radius. Or, the longer ſemidiameter may be the Radius, and the ſhorter ſemidiameter muſt then be the Sine of the elevation of the Pole above the plain.

Upon theſe two extream diameters thus limited, may the Ellipſis be deſcribed with Elliptical Compaſſes. Or otherwiſe it may be done by two Circles, the one circumſcribed, the other inſcribed, both divided into like parts, and ſo points found through which the Ellipſis is to paſſe, as in the former direct plains was preſcribed, and through thoſe points the Ellipſis may, with a ſtedfaſt hand be deſcribed. In right Horizons or Polar plains there will be no Ellipſis at all, but it vaniſheth into a ſtreight line only.

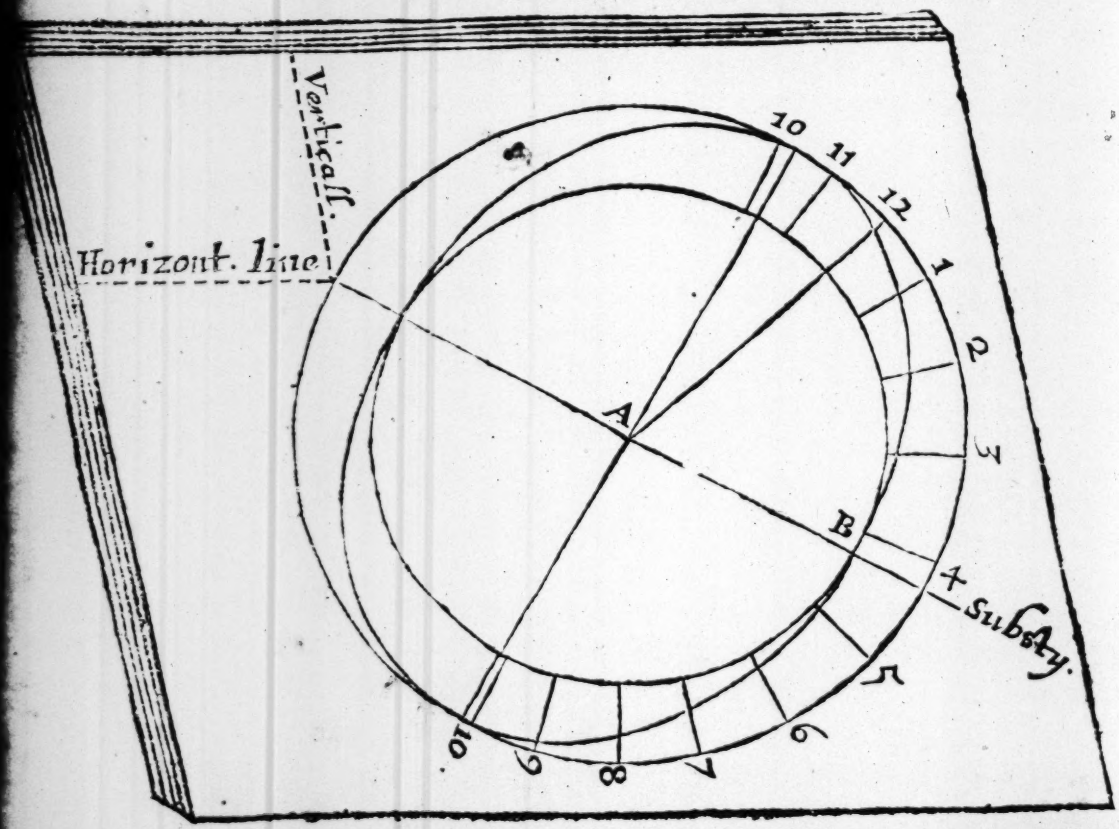
How to divide the Ellipſis into ſuch requiſite parts as the plain ſhall require.

If you ſhould put in the houres proper to the plain there will be no difficulty, for then the ſubſtilar being taken for the line of 12, the houres muſt be drawn as before was ſhewed in direct plains. For in this caſe the Dial is Horizontal, ſhewing the houre of the day to all places that lie under that Meridian under which the plain it ſelfe lyeth. But

If

If you would put in the houres of the place (as moſt frequently is deſired) then you are to work (for the diviſion of the Ellipſis) either by calculation or by protraction. If you calculate for the Ellipſis, you muſt firſt forme all the angles at the Pole as the manner is in theſe kindes of Dials: Then you are to invert the terms of proportion from the common way of calculating ordinary Dials, and ſay thus:

As the Sine of the Poles elevation above the plain,
Is to the Radius;
So is the Tangent of each angle at the Pole,
To the Tangent of the angular diſtances of all the houres from the ſubſtylar line of the plain.



Suppoſing

Suppoſing therefore that you had your Ellipſis before deſcribed, and the ſubſtilar line ſet off from the plains Vertical line in its true poſition, you may from that ſubſtylar line (and by the horary ſpaces found by calculation) ſet in every houre point into the Ellipſis, by help of any Circle deſcribed upon the center A. As you ſee here are two Circles, the circumſcribed and the inſcribed, either of which, or any other circle elſe, will ſerve to prick on the houres by. The houre-points are here ſet upon the circumſcribed Circle, and transferred into the Ellipſis by a Ruler laid to A, the common center of the Ellipſis and of the Circle. This is one way, and is beſt done by calculation: here you may alſo put in the halves, and quarters, and halfe quarters of houres, or what other parts you ſhall beſt like of.

How to limit the Ellipſis, and divide it, without Calculation.

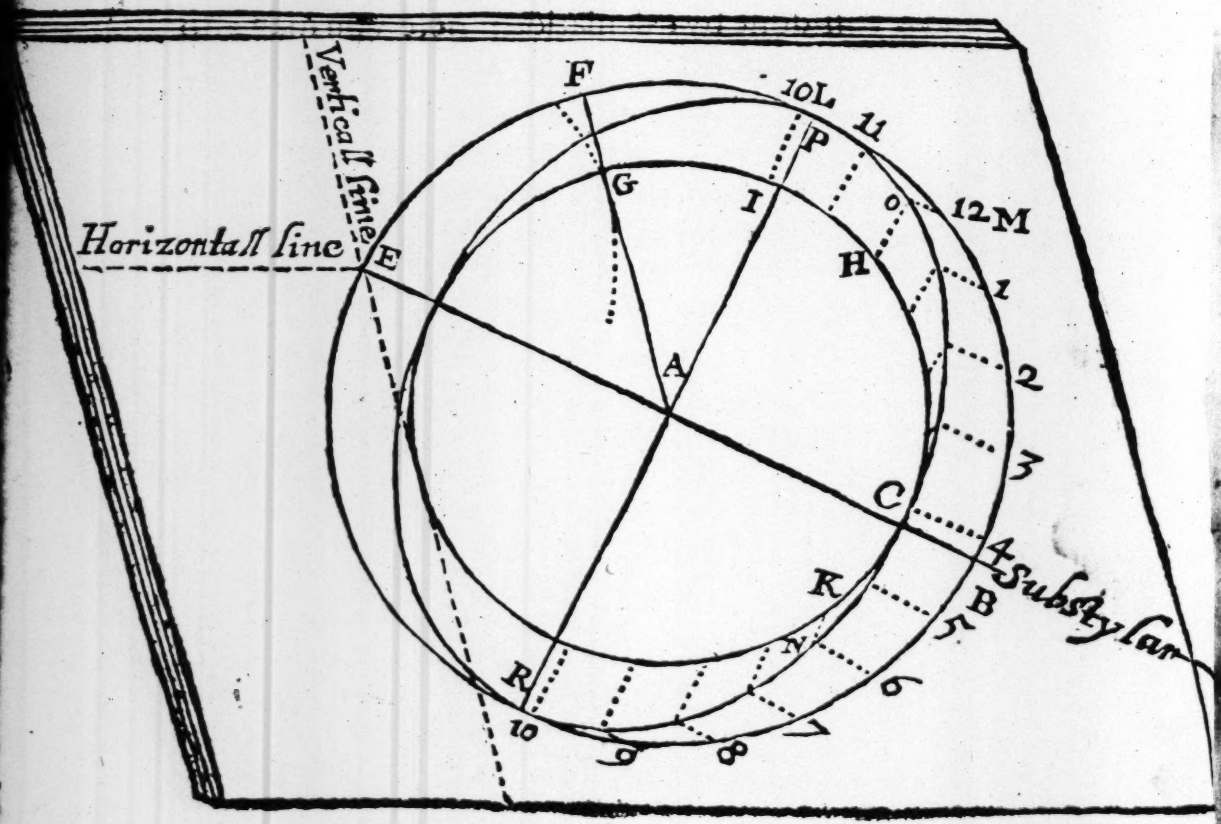
But if you are deſirous to do it rather by protraction, then muſt you work ſomwhat as formerly was done, the manner I will in briefe ſhew, wherein you may ſee the way both how to deſcribe the Ellipſis, and alſo how to divide it, all under one.

1. Having prepared all neceſſary requiſites before hand, you muſt firſt ſet off the ſubſtilar line in its true poſition from the Vertical line, which to do, I here ſuppoſe already known. So in the following figure you ſee A C B drawn for the ſubſtilar line, or the proper meridian of the plain.

2. Upon this plain, and upon ſome point of the Subſtylar line, as at A, as upon a center, deſcribe the Circle B M E, and quarter it, and let the Semidiameter of that Circle be counted as the Radius.

3. Upon one of the quarters, ſet off the Poles elevation as from E to F, and draw A F, and from E to A F take the leaſt diſtance, as E G, and with that diſtance, upon the former center A, deſcribe another leſſer Circle as C H.

4. From B (where the greater Circle cuts the ſubſtylar) ſet B M equall to the plains difference of Longitude: and from M divide that exterior Circle into 24 equal parts, which ſignifie the 24 houres; and by a Ruler laid to the common center A, transfer them into the leſſer Circle, as M H, 10 I, 6 K, &c.



5. From

5. From every point in the great Circle, draw lines parallel to the ſubſtylar, and from every point of the leſſer Circle draw lines perpendicular to the ſubſtylar, or parallel to the longeſt diameter PAR, and ſo each couple of theſe lines ſhall cut each other at right angles.

6. Note where every line thus drawn from any point of the greateſt Circle, meets with the other line which is drawn from the like point in the leſſer Circle. For the concourſes of theſe anſwerable lines are the points here required. That is, Thoſe are the points which ſhew both where the Ellipſis is to be drawn, and alſo where it is to be divided into its requiſite parts.

Thus in the precedent figure: M O and H O meet in the point O, 10 L and I L meet in the point L, 6 N and K N meet in the point N, and ſo the reſt will meet in their due places. Theſe points ſhew the way where through the Ellipſis is to be drawn, and the ſame points ſhew where the houres are to be marked out. The like may be done for quarters and halfe quarters of houres, or any other diviſion that ſhall be beſt liked of.

There are many other wayes to do the ſame things, but I ſuppoſe this to be moſt expedient.

Note: that

1. The Index in theſe Elliptical Dials muſt ſtand perpendicularly upright upon the plain, making right angles with it every way, as it was ordered to do upon the former ſort of direct plains.

2. The annual course of the Sun must be limited as formerly in the other plains, that is, making the greater semidiameter as a Radius, you must finde the Co-sine of the Poles elevation above the plain. This Co-sine is to be made either as a Tangent of 45 *gr.* whereof you are only to use $23\frac{1}{2}$: Or else it is to be made a Decimal Scale. By both these you have Tables and Rules how to compleat the Suns annual course, either in degrees of the Signes in the Zodiac, or by the dayes of the 12 moneths.

3. Either the Index must move and the Ellipsis lie still, or contrarily. Every man in this must do as his invention shall best suggest. And that motion must be made either upon the substylar line, or else parallel to it, which way soever it be, it must be precisely and punctually ordered.

4. All other things concerning the time of Sun rising and setting, the Suns Amplitudes and Declinations, may here (in the same manner as before) be inserted either proper to the plain, or proper to the place, as shall be desired.

5. In right Horizons or Polar plains, the Ellipsis closeth quite up into a streight line: and so the division of it is only by the exterior Circles parts projected upon it by those lines that are drawn parallel to the substylar.

Thus far of the Elliptical Dial, as it is to be described upon declining plains whose Indexes stand perpendicular to the plains, and which do not lie under the Meridian of the place but swerve from it.

SECT.

Latitude 51 *gr.* 30 *min.*

Hor	*Ang.*		*Altit.*		*Hor*
XII	00	00	38	30	XII
	04	47	38	24	
	09	33	38	7	
	14	16	37	38	
XI.	18	54	36	58	I.
	23	27	36	7	
	27	53	35	7	
	32	13	33	56	
X.	36	25	32	37	II.
	40	29	31	10	
	44	26	29	36	
	48	15	27	54	
IX.	51	57	26	7	III.
	55	32	24	14	
	59	1	22	16	
	62	24	20	14	
VIII	65	41	18	8	IV.
	68	54	15	59	
	72	2	13	47	
	75	7	11	33	
VII	78	9	9	17	V.
	81	9	6	59	
	84	7	4	39	
	87	4	2	20	
VI.	90	0	0	0	VI.

SECT. III.

Another way to prick down the Ellipsis *upon an Horizontal Plain.*

FOr this purpose here are two Tables joyned together, both of them made for the Latitude of *London*, 51 *gr.* 30 *min.* the like to which every man may calculate for his own place.

The first of them is a Table of such angles as are made by the hour lines (coming through the center of the Ellipsis) with the Meridian line or line of 12. And it was made by that rule which was given (in this case) at the beginning of this Treatise. Namely,

As

As the Sine of your Poles elevation (wch is here 51 *gr.* 30 *m.*)
Is to the Radius;
So is the Tangent of each houre and their quarters (counted from 12 a clock,)
To the Tangent of the angle required.

The ſecond Table is of the Altitudes of each houre and quarter, in the Equinoctial Circle, above the Horizon; and it is calculated by this Rule.

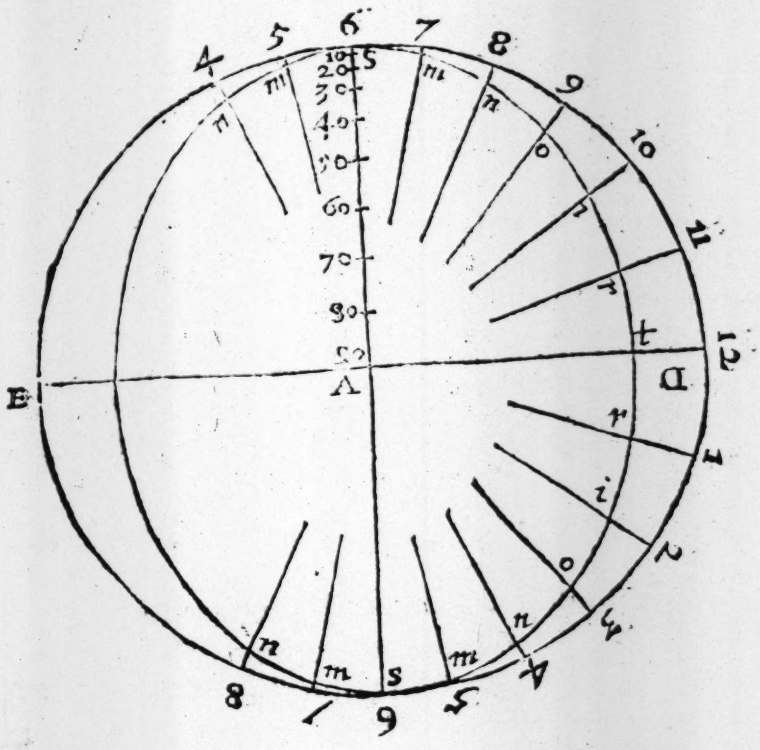
As the Radius,
To the Co-ſine of your Latitude (which is here the Sine of 38 *gr.* 30 *min.*)
So is the Sine of each houre and their quarters, (counted from 6 a clock,)
To the Sine of the altitude which is here ſought.

Then having computed theſe two Tables, you may (by help of them) both draw and divide the Ellipſis into its true houres and quarters by theſe following directions.

Firſt, draw the two lines 6 6 and D E, croſſing each other at right angles in A, and let A D be the Meridian, and 6 A 6, the two ſix a clock lines.

Then upon A as a center deſcribe the Circle 6 D 6 of any convenient bigneſſe; and upon the ſame Circle from D (on both ſides of it) ſet on the houres and their quarters, as 11 and 1, 10 and 2, &c. by help of the degrees and minutes of the angles ſet to every houre in the former Table. And through every of theſe points inſcribed into the Circle, draw lines from the center A, as A 11, A 10, A 1, A 2, with the reſt of the houres and their quarters if you will.

Thirdly, ſuppoſing A 6 to be the Radius, you may divide



it into 90 Sines; the beginning or largeſt parts whereof muſt be at A, but the numeration muſt be the contrary way, beginning at 6 and ending at A in 90. Or you may take the complements of the former Altitudes in the Table, and take them out of a line of Sines numbered the right way, which will be beſt for the Sector, or ſuch Inſtruments which will beſt perform this work without any great trouble.

Fourthly, looke in the ſecond Table for the altitudes of the Equinoctiall at every houre. Then count thoſe Altitudes in the line of Sines, and take with your Compaſſes the ſeveral diſtances of them from A, & tranſfer the ſaid diſtances from

from the center A to every houre reſpectively, ſo ſhall thoſe interſections give you the points through which the Ellipſis muſt be drawn.

Thus the altitude of 7 and ½ a clock (which is 9 *gr.* 17 *m.*) being taken upon the line of Sines from A towards S, is inſerted into 4 houres at the note *m*. And the altitude at 8 and 4 (which in the Table is 18 *gr.* 8 *min.*) being taken and transferred to the four houres at *n*, do give four points more. The reſt of the altitudes give (each of them) two houres only, as at *o*, *i*, and *r*, is done. And the laſt of all at 12, gives one only point at *t*. The like may be done for the quarters. And ſo through theſe points thus found the Ellipſis may eaſily be drawn, and the lines formerly drawn give the diviſions that are due unto it.

Note.

1. This is propounded only for Horizontal plains, but it may without difficulty be applyed to any other direct plain. The trouble that is, comes by reaſon that the foreſaid plains have a different elevation of the Pole, from that elevation that belongs to the Horizon or place where they are to ſtand: and conſequently there will be required two new Tables for that elevation which is proper to the plain; the calculation of which will eaſily be done by the two former proportions ſet down for that end. Note further that by theſe two Tables you may prick down an Ellipſis upon any leaning (not upright) plain whatſoever. But the Index muſt then lie in the Zenith line of the place, (not of the plain) and the Ellipſis (or Index) muſt move in the Meridian of the place (not of the plain) and the Zodiac muſt be like or proportional to the Zodiac of the Horizon, but augmented, for the moſt part, in this proportion.

As

As the Radius,
To the Secant of that angle that the Meridian line (upon the plain) makes with the Horizon; (which angle must be gotten by a Clinatorie:)
So the Radius of the Horizontal Zodiac, (which is the Co-sine of the Latitude,)
To the Radius of the Zodiac proper to the plain: which Zodiac must be set according to the line of 12 upon the plain.

2. This way of delineation may likewise be applyed to all other plains which decline, and are not direct. But in these will be found more difficulty then in the former plains which declined not, unless it be required to put in the houres that are proper to the plain; for in that case the work is the same which was in them. But if the houres of the place are to be inscribed, as most usually they are, then there will be some trouble, by reason that the difference of the plains Longitude seldome falls upon any just houre. I purpose not here to shew the way, it being such as will prove un-pleasant to the unskilfull, and such as have knowledge will finde it out quickly. Perhaps the pleasure of the thing done, will recompense their labour.

SECT. IV.

Here follow ſome Uſes and Varieties of this Ellipticall Diall.

USES.

FIrſt, If the Index ſtand ſtill, and the Ellipſis be made moveable; you may upon that plate which is immoveable, and on which the Index ſtandeth, deſcribe a Circle, whoſe center muſt be the foot of the Index. And drawing a Meridian line upon the ſaid immoveable plate (juſt under the Meridian of the Ellipſis, and) from the foot of the Index you may divide that Circle (beginning from the Meridian line) into 360 *gr.* or ſo many of them as ſhall be needfull. By theſe degrees you ſhall finde the Suns Azimuth by the ſhadow of the upright Index, and by the diviſions of the Ellipſis you may know the houre of the day. So both Azimuth and Houre are ſhewed upon the two plates by one upright Index.

This kinde of Diall muſt be ſet in its true poſition (for it will not ſet it ſelfe) and muſt there be fixed. If it be upon an Horizontall, or any direct plain, you may draw a Meridian line thereon, and either draw the Azimuths true upon it, and ſo make the Ellipſis to move to and fro according to that Meridian: Or elſe, if both your plates be to be fixed upon any Baſe prepared for them, you may, firſt, upon that Baſe draw a true Meridian line, and to that line make the Meridian of the Diall to agree. The

The like muſt be done in all declining flats, onely you muſt be carefull to make the ſhorteſt Diameter of the Ellipſis (which is the proper Meridian of the plain) to agree with the ſame proper Meridian, as it ſhall firſt be drawn upon the Baſe in its true poſition.

2. A ſecond excellent uſe may be for the ſetting of moveable Dials, ſuch as are made to ſtand out of the weather, and are only to be ſet in the Sun at pleaſure, when the houre ſhall be required. Of this kinde are Polyhedrall Bodies made of ſome light matter, and Concaves, &c. But it is ſuppoſed that ſome of the ſuperficies of ſuch Bodies, (&c.) have the houres of the place deſcribed upon them the ordinary way, by the Axis of the Equinoctiall, and that this Ellipſis is fitted to ſome one plain (which principally is the Horizontal plain (becauſe that alone will ſhew all the houres of the day) or in ſome Horizontal poſition to the concave, or any ſuch Diall) in its juſt poſition, and alwayes with an upright Index, (that is, an Index perpendicular to the plain whereon it ſtands) which is nor alwayes upright in reſpect of us, but only in reſpect of the plain) and with the houres alſo of the place. Theſe things being ſo fitted, you may place your Body or Concave in the Sun, and turn it about till you diſcern that both kindes of Dials do agree to ſhew one houre, which when they do, then all ſtand right in their true ſituation, which will never elſe happen but only when the houres do in both agree.——To this place is referred the Double Horizontal Diall, the one of them giving the houre by the Axis, the other by the upright Index.——And here it muſt be noted, that the worſt time of the day for this ſetting the Dials in a true poſition, is at the neereſt to noon, and the beſt time is about the Suns being in the Eaſt and Weſt Azimuth.

3. This kinde of Diall may be placed (in a moveable

poſture) before a caſement in any window that hath a flat board upon which it may move. And the Index to it may be an upright threed (preciſely upright it muſt be) that is fixed at the top and bottome of the window, to and from which the Ellipſis muſt move in a Meridian line that is drawn upon the board of the window, & from or juſtly even upon the threed. ——— And where I ſay the window muſt be flat, it is to be underſtood that there is no extraordinary exactneſſe required in that. For if it ſhould riſe or incline 5 *gr.* to the Horizon, it would not erre one minute of time about our Latitude; provided that the Meridian be truly drawn, and the Index perfectly upright, in which all poſſible exactneſſe is required.

4. If any choiſe plain reclining, or however ſituated plain that ſhall repreſent the Horizon of ſome notable place, be fixed as a Baſe whereon to place ſuch a Diall thus fitted, and drawn to the proper houres of that ſame place: this double Diall being placed upon that Baſe, and turned about thereon, will ſhew the true houre at that place when both of them do agree, and the Meridian of it will ſhew how the proper Meridian of that place is to be placed, and which way drawn.

5. If ſuch a Recliner (or Incliner, or Erect) ſhall be furniſhed with ſuch a double Diall to ſome intended Declination, though they ſtand and be framed properly to the plain in reſpect (chiefly) of the upright Index, and ſhall (notwithſtanding) have the proper houres of the place upon both Dials: and if further ſuch a Recliner as was mentioned, have an horizontal baſe, upon which it may be turned round: I ſay, though this Body be horizontally moveable, and may be turned any way, yet the two Dials will never agree

to

to ſhew the ſame houre, untill the Baſe ſtand to the true Declination to which the double Diall was drawn.

SECT. V.

Some varieties of the ſtructure of it do here follow.

FIrſt, Inſtead of the Ellipſis drawn to the proper Meridian and Latitude of the plain, there may be uſed a true Circle equally divided: but then let theſe things be obſerved.

Firſt, That the Index muſt be perpendicular every way to the plain on which the Circle is elevated, ſtanding upright upon it. Secondly, That the motion (either of Index or Circle) muſt be according to the proper Meridian of the plain. Thirdly, That the Zodiac muſt alſo be proper to the plain, and muſt lie upon the plain or Baſe it ſelfe, and muſt be the ſame with that which ſhould ſerve for the Ellipſis. But then, Fourthly, this equally divided Circle muſt be elevated over the proper Meridian of the plain (that is, the Baſe of it muſt reſt upon the proper Eaſt and Weſt line of the plain) ſo much it muſt be elevated as the elevation of the Equinoctiall above that plain comes unto. And the elevation of it may be either way; that is, either upon the South Coaſt, and then it will be anſwerable to the Equinoctiall in the heavens; or elſe it may be towards the North, but ſtill ſo much as the Equinoctials (not the Poles) elevation comes unto, and in ſome caſes it muſt be done both wayes

wayes that the Sun may come at it, and it muſt then have two Indexes. Both wayes it is alike true. It muſt be divided into equall houres and parts, and ſo much of it muſt ſtand above the Baſe or plain on which it moves, as the longeſt day comes unto. The beginning of the diviſion muſt be from the line of 12, and if the plain be not direct, then muſt the difference of Longitude be counted in the circular degrees, from the higheſt point, or from the Vertical line of this Equinoctiall Circle.

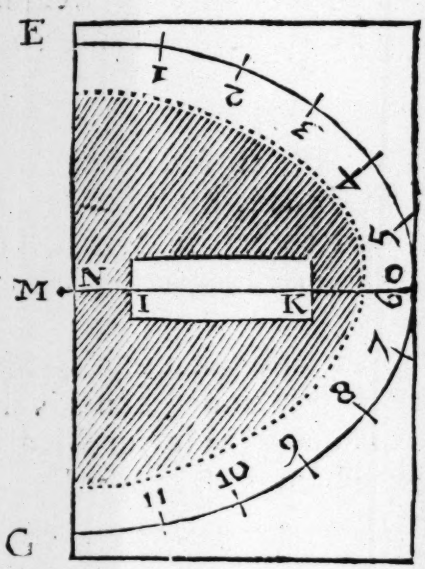
2. This Diall is not ſo tyed to a plain, but that it may alſo be brought to an un-even Superficies, yet ſo, that the motion of it, or the Zodiacal Scale muſt be upon ſome plain. But to ſhew the manner how this ſhould be performed, is more proper for thoſe Projecting wayes which I have in another place had ſome aſſayes of. Only remember that the Horizontal Diall muſt be projected, not by the Axis, but by the Zenith.

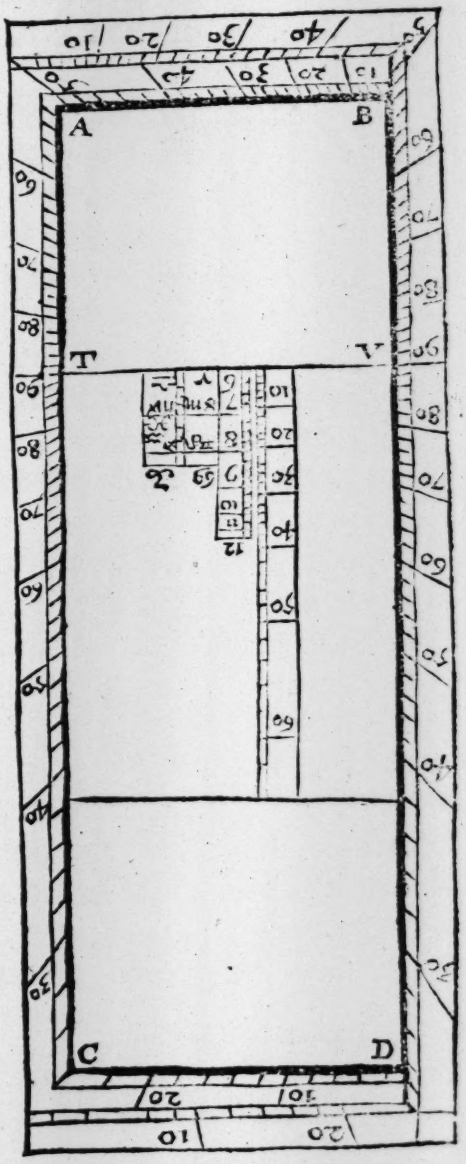
3. A double Diall depending upon this kinde, may be made to ſet it ſelfe, and to ſhew the houre in a Craticular forme, which is alſo more properly to be handled in my other wayes.

There remains yet one ſtructure more, by which it is fitted for ſome uſes that follow after, and is made a portable Inſtrument, not at all to be uſed in obſervation.

1. MAke a right angled Parallelogram, as A B C D, whoſe length may be about three times the breadth: and let the limbe (upon which the graduations ſtand) be higher then the Plain or Area of it.

2. De





2. Deſcribe a Semiellipſis to your own Latitude, whoſe longeſt Radius let be M O, a little longer than A B, that when the center M is left out and cut off, ſo much as M N comes to (which may be about halfe a quarter of an houre from 12 in the Ellipſis) the remaining breadth N O, or E F, or G H, may be juſt fit to A B the breadth of the hollow Area, in which this leſſer rectangled Parallelogram E F G H may be moved to and fro as there ſhall be occaſion. And let the thickneſſe or depth of this moving plate be the ſame

ſame with the thickneſſe of the limbe of the lower plate. The diviſion of the Ellipſis may be made according to the rules before given.

3. In the midſt of this leſſer plate, let a hole be pierced quite through it; and in that hole let a threed be extended, as I K, which is to ſerve for an Index, by which the ſaid Semiellipſis is to be rectified. And therefore it is beſt that the threed I K be laid juſt in the longer diameter, which is the 6 a clock line.

4. Take the leſſer Parallelogram and put it into its place, as cloſe to the end A B as it will go, and when it is there laid, obſerve where the threed lies upon the lower Area, and draw the line upon which it lies, which muſt be the line 90, 90; upon which the Scales (that are inſcribed) muſt take their beginning. And likewiſe you are to take the longer Radius O M, and as the plate there lies, ſet one foot of that Radius upon O, and let the other reach as far as it will, which muſt be upon the riſing limbe beyond the inner edge of it, ſo much as M N comes to: in that point you are to make one center: ſo again, turning your leſſer plate about, you muſt lay it in the contrary way, cloſe to A B, as you did before, and from the point O you may finde the ſecond center: both theſe centers (in each of which muſt a threed be faſtned) will happen to fall in the former line 90, and 90, neer the points T and V.

Being thus far prepared, you may take away the leſſer plate, and divide the Scales upon the greater plate, in this manner.

5. Firſt, For the two limbs of it, they are nothing elſe but

but the degrees of a Circle projected thereon from the two centers: which may therefore without difficulty be done either from the degrees of a Circle, or elſe by Tangent lines, as any man will eaſily perceive.

6. Secondly, For the other Scales you muſt make them parallel to the edge of the limbs. There are three of them in number: The longeſt is a Scale of Tangents: The middlemoſt is a Scale of houres, made in the form of a line of Sines: The third is a Zodiac, or Scale of the year.

The Tangents are made thus. Taking M O as Radius, finde the Co-ſine of your Latitude agreeable thereto: and making that Co-ſine as a Radius, or Tangent of 45 degrees, all the other Tangents are to be fitted accordingly. Then to know how far of this line will be uſefull, put the leſſer plate again into its place, as cloſe to the end C D as it will go, ſo ſhall the threed I K ſhew the furtheſt point of it that will be uſefull.

The middle Scale of Sines is made thus. Count the complement of your Latitude upon the new made Tangent line, and from the beginning of the Scale to that point, make a line of Sines for ſix houres and their quarters, ſo ſhall this Scale be fitted.

The Zodiac or Annual Scale is equall in length to the Tangent of 23 *gr.* 30 *min.* and the manner of inſcription with Tables whereby to do it, are ſet down before, and need not be here repeated.

The reaſon why this Inſtrument is thus contrived.

The intent of the contrivance is, that it ſhould ſhew both Azimuth and houre, and that therefore there ſhould be a Circle and an Ellipſis ſliding over it, both of them made to

one center, ſo that the center ſhould be in the midſt, and the Circle ſhould be a whole entire Circle, and the Ellipſis alſo whole. But becauſe the Ellipſis ſliding upon the nether plain, doth ſomtimes of neceſſity cover the center, ſo as that there can be no threed fixed for uſe, I was therefore compelled to order it in this manner that is before expreſt, that the motion of the upper plate and the centers might ſtand cleere without hindring each other.

Then further it muſt be noted, that the Inſtrument is (not generall to all, but) particular to one Latitude.

The uſes of it do here follow, which by reaſon of the Semi-ellipſis will not be ſo eaſie, becauſe many changes are required. In generall note thus much.

1. In uſing this Inſtrument you muſt alwayes ſuppoſe that you looke upon the North.

2. If the Declination of the Sun or Star be North, hold A B towards you. If South, then hold C D towards you.

3. If the Sun or Star be Eaſtward of the Meridian, let the morning houres be towards you. If they be Weſtward, let the evening houres be towards you.

4. Alwayes uſe that threed which is on the ſame ſide with the center of the Ellipſis. And that ſide line of the larger plate is ever to be taken for the Meridian, and conſequently the other ſide muſt be eſteemed for one of the two Coaſts of Eaſt or Weſt.

5. Becauſe North is furtheſt from you, therefore the furtheſt quarter of the limbe muſt be either North-eaſt or North-weſt: the neereſt South-eaſt or South-weſt.

Theſe cautions being obſerved, the concluſions that are to be wrought will be eaſie.

I

1. *By having the Azimuth to finde the Houre.*

First, Order your Instrument by the former cautions, according to the present case of your observation. And rectifie the upper plate (by help of the threed Index) either to the Declination of the Star, counted in the Tangent line, or to the Suns place in the Zodiac. Then count the Azimuth given upon the right quarter of the limbe, and apply the threed thereto: So shall the threed shew (upon the Ellipsis) the houre in which the Sun or Star is.

If the work be for the Sun, then the houre thus shewed is the Suns houre, or houre of the day.

If the work be for a Star, it then shews the Stars houre only; which must afterwards be reduced into the Suns houre, that it may be the true houre of the night. This change may most easilie be done by a common Nocturnall.

2. *By having the Houre in which the Sun or any Star is, the Azimuth thereof may be found.*

The Instrument being rectified; lay the threed upon the houre (counted in the Ellipsis) the same threed will shew the Azimuth in the graduations upon the limbe.

3. *To finde the Aſcenſionall difference, the Semidiurnall and Seminocturnall arkes, with the time of their riſings and ſettings.*

In generall note this: If the Sun or Star decline Northward, then the Semidiurnall arke is greater than ſix houres; if Southward, then leſſe.

The upper plate therefore being rectified, either to the Suns place, or to the Stars Declination, the threed will ſhew upon the middle Scale, the Aſcenſionall difference, if you count the houres how many they are from *6*. It ſhews the Seminocturnall arks, by the houres of ſetting and riſing being rightly taken according to the condition of North or South declination. It ſhews the time of Sun riſing and ſetting, according to the houres upon which it lies. But for the Stars, it ſhews only upon what houre-circles they riſe and ſet; but the true houre or time thereof muſt be found by turning the Stars houre into the Suns houre, which (as I ſaid before) will be done with moſt eaſe by an ordinary Nocturnall, in which the Stars (that you deal with) are placed.

4. *To finde the Amplitude of their Riſings and Settings.*

When your upper plate lies ſo rectified, lay the threed upon the Ellipſis, to the Aſcenſionall difference, or Semidiurnall

diurnall arke before found. The threed ſo laid, will ſhew the Amplitude in the limb of the Inſtrument.

Note here.

In the firſt of theſe Propoſitions I ſuppoſe the Azimuth, in the ſecond I ſuppoſe the Houre to be given by obſervation. For the obſerving of theſe two, you may make in any convenient window, both an Horizontall Diall, with a threed Axis lying in the Axis of the world, and an Azimuth Circle with a threed Axis, ſtanding upright in the Zenith line. The diviſions ſutable to both theſe, may be inſcribed upon the board of the window; and for the Sun, the ſhadow of the threed will give the houre of it upon the Horizontall Diall; or the Azimuth upon the Azimuthall Circle. But for the Stars that caſt no ſhadows, you may make ſliding ſights, that may move upon the edge of the window board, or may lie upon the board it ſelfe, (which muſt in theſe reſpects be level, or at leaſt neer to it.) And thoſe moving ſights muſt be furniſhed with ſhort wires or pins which may beſt ſtand upon the edge of the ſight, and go down to the window board, and to the diviſions that are drawn upon it, which may be both for ſights by which to looke at the ſtanding Index and Star both together, and muſt ſerve as Indexes to ſhew the houre or Azimuth on which a Star is at any time. Only this generall caution muſt be given, that theſe pins be ſet parallel to the threed Axis that is ſet in the window (that is) for the Azimuths they muſt ſtand upright, but for the houre they muſt lie aſlope, parallel to the Axis of the world. This I have ſometimes done, and this any man may at his pleaſure do, whereby either the Houre or Azimuth may be obſerved, and when any one of them is known;

known; this Inſtrument (now deſcribed) will finde the other. In ſuch like caſes this Inſtrument will be delightfull and of good uſe.

5. *To finde the Declination of the Sun.*

Set the threed of the upper plate upon the Suns place in the Zodiac, or upon the day of the moneth in the Annual Scale, the ſame threed will give the Declination thereto belonging, upon the Tangent Scale.

6. *How to make an Horizontall Diall by this Inſtrument.*

The meaning is to know how many degrees are intercepted between the Meridian line, and any other houre line. There are two wayes to do it. The firſt is the converſe of the making of the Inſtrument. For if the threed Index be laid to the line where the Scales of the lower plate begin, ſo that the line of ſix do lie evenly between the two centers where the threeds are faſtned, then the center threed applyed to the houres ſeverally will ſhew how much they are gradually diſtant from the line of 12. But you muſt here remember to take 6 for 12, and 7 or 5 for 11 or 1, and ſo the reſt of the houres in that order. And the graduall ſpaces or diſtances from the Meridian or line of 12, muſt be counted from 90 contrary to the numeration of the limb. But this is not ſo artificiall as this that now follows.

S

Set the moving plate to any houre upon the middle Scale, and apply the center threed to the like houre in the Ellipsis taken on that side of it that is furtheſt from the beginning of the three Scales, and it will ſhew you (upon the limb) the angle or Horizontall ſpace that is due to that houre. The like is to be done in every other of the houres.

SECT. VI.

AN ADVERTISEMENT

Concerning ſome other uſes of the Inſtrument that was laſt deſcribed.

SInce the writing of that which is gone before, other things there are which came into my thoughts concerning the further uſe of this Inſtrument.

It were more expedient therefore that the Ellipſis were divided into houres and degrees, rather then into quarters and half quarters of houres. Which diviſion (as alſo the deſcription of it) may by protraction be performed by thoſe rules that are given before. But if it be thought better to do it by Tables; then by the former rules of calculation given for this work, you may frame two Tables, the one of Angles, the other of Altitudes to your own Latitude, ſuch as in the following Table are computed to the Latitude of *London*. By theſe Tables you may put in every houre and third degree,

Ad Latitudinem 51 gr. 30 min.

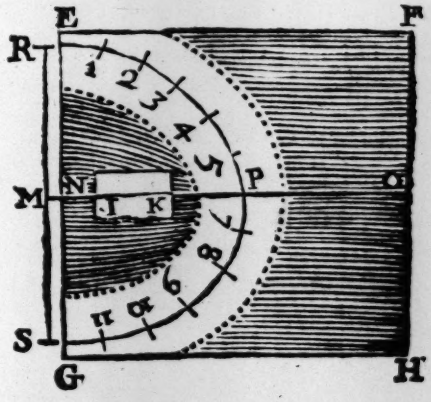
Hor	gr.	Angles		Altit.		gr.	Hor
XII	00	00	00	38	30	00	XII
	12	3	51	38	26	3	
	9	7	39	38	16	6	
	6	11	26	37	57	9	
	3	15	12	37	31	12	
XI.	00	18	54	36	58	00	I.
	12	22	33	36	18	3	
	9	26	08	35	32	6	
	6	29	38	34	40	9	
	3	33	04	33	41	12	
X.	00	36	25	32	37	00	II.
	12	39	41	31	27	3	
	9	42	52	30	14	6	
	6	45	59	28	56	9	
	3	49	00	27	33	12	
IX.	00	51	57	26	07	00	III.
	12	54	50	24	37	3	
	9	57	38	23	04	6	
	6	60	23	21	28	9	
	3	63	04	19	49	12	
VIII	00	65	41	18	08	00	IV.
	12	68	16	16	25	3	
	9	70	47	14	40	6	
	6	73	17	12	53	9	
	3	75	44	11	05	12	
VII	00	78	09	09	17	00	V.
	12	80	33	07	26	3	
	9	82	56	05	35	6	
	6	85	18	03	44	9	
	3	87	39	01	52	12	

gree, the intermediate degrees may be equally divided. The numeration will be either by 15, 30, 45, &c. according as the signing of it by hours wil require; Or else besides the houres you may set on 10, 20, 30, &c. in small figures, which will stand without hindring the numbers (or numerall letters) that are set for the houres.

This Ellipsis thus divided, may represent either the Horizon, or else any of the (*Almicantars* or) parallel circles to the Horizon; & the divisions of it must then signifie the Azimuths. And if it be too big (especially when it comes to represent any of the higher *Almicantars*) you may adde another sliding plate of the same breadth that the former was, nam-

M O here equall to M O in the former, and M N muſt in both be juſtly equall, that it may both ſlip in the former cavity, ſo as juſt to fill it, and that the ſame limbs, centers, and threeds, may in both agree.

But then a leſſer Ellipſi muſt be here deſcribed and ſo the length G E or F H will be diminiſhed.



A leſſer Ellipſis (I ſay) muſt be deſcribed, which though it be leſſe, yet it muſt be like and proportionall to the former.

Therefore aſſuming any length as M P, for the longer Radius, you muſt (to that Radius) make M R and M S equall to the Sine of your Latitude, and ſo deſcribe and divide it as formerly was ordered.

Then again, to this new Ellipſis there muſt a new Scale of Tangents be made, whoſe length muſt be limited as the former was, in this manner. To M P as Radius, finde the Co-ſine of your Latitude, and make that Co-ſine a Radius or Tangent of 45 *gr.* and according thereunto, continue the Scale of Tangents as far as it will go. It muſt begin upon the ſame line that the other Scale of Tangents began, and muſt go the ſame way with it. And in this new way of ordering the Scales and the Ellipſes, it muſt be conſidered what the other parts of the Inſtrument do ſignifie

The end of the lower plate, upon which the Scales begin, muſt be accounted for the North, the other end C D is to be taken for South. The ſide lines are the Meridian. The degrees of the limbs are to be uſed as the degrees of

the Equinoctiall. The threed applyed to thoſe degrees are the Meridians comming from the Centers, which are the North Pole. The Tangents are the degrees of Altitude. The Ellipſis notes out that Almicantar which the threed Index ſtands unto upon the Tangent Scale.

And further. It is to be here noted, that if the Meridians (or threeds comming from the center) were rightly divided, thoſe diviſions or parts of it ſhould ſignifie the degrees of Declination from the Equinoctiall. But the inconvenience of it is, that becauſe one Ellipſis is to repreſent every Almicantar, therefore the Radius cannot poſſibly be at all times the ſame in length, but muſt varie according to the removing or ſeverall poſitions of the ſaid Ellipſis. That is, when the Ellipſis ſignifies the Horizon (or ſtands at the beginning of the Scales, without any altitude at all) then the Radius M O in the firſt moving plate, or M P in the ſecond moving plate, is the Scale of Declinations, but at other times, when the Ellipſis ſignifies any Almicantar, then muſt the Secant of that Almicantar (of Altitude) be taken as the Radius for that particular work. But alwayes the Radius (of what length ſoever it be) muſt be divided as a whole line of Sines, the greateſt parts beginning towards the center, the leaſt parts ending at the remoteſt end from the center, and yet then again, the numeration of the parts or declinations of it muſt begin at the remoteſt end, and muſt end in the center at the Pole.

It might be applyed to uſe in the motions of the Stars, but that would be troubleſome; therefore it ſhall ſuffice to make it uſefull only for the Sun.

The beſt way that (for the preſent) I know whereby to divide this Radius (thus of ſeverall lengths) is this. Divide the length from the center T to C into 90 Sines (the greateſt

greateſt parts beginning at the center, but numbered the contrary way.) This line may be drawn from the center T into ſome part of the limbe, where it may have room to receive diviſions. Then with your Compaſſes take the Radius T V, equall to M O, and from the end of the former Scale, open the threed to the leaſt diſtance, and where the threed ſtayes, there make a mark upon the limbe V D, for there is a new Scale to begin, for the Secants that were mentioned before.

Then lay the threed from T to 80 in the oppoſite limb, and move the Ellipſis till the point O fall juſt under the threed, and take T O in your Compaſſes, and put in that diſtance as before, ſo ſhall you put in 10 *gr.* into this new Scale. In like manner lay the threed to 70, 60, &c. and bring the Ellipſis till the point O lies under it, ſo ſhall T O (in theſe ſeverall poſitions) give the lengths to be inſcribed in this new Scale, for 20 *gr.* and 30 *gr.* *&c.* all the reſt muſt be done in like manner, till you have put in as many as will come within the reach of the limb, which will be upon 60 *gr.* or thereabout.

The like ſhould alſo be done for the leſſer Ellipſis, working in the ſame manner by the threed and the point P. Theſe are called the new inſcribed Scales.

The former line of Sines ſerves to them both indifferently.

Now when things are thus fitted, the uſes of them will be ſuch as in particular Aſtrolabes is vulgarly known.

Some of the Uſes are here mentioned.

1. *Having the Suns Declination and Altitude to finde the Houre and Azimuth.*

First, For North Declinations. Set the Ellipſis to the Altitude counted in the Tangent Scale. Then count the ſame Altitude iu the new inſcribed Scale of Secants, and thereto lay the threed. Afterwards, take the leaſt diſtance from the Suns declination, (counted in the fore-mentioned inſcribed Scale of Sines) to the threed. Set one foot of that diſtance in the center, and extend the other till it croſſe the Ellipſis, and where it croſſeth, thither apply the threed, which (in the limb) will ſhew the Houre and ſcruple (in degrees) required. The ſame point of the Compaſſes doth alſo immediately ſhew (upon the Ellipſis) the Azimuth ſought for. If the Compaſſes do croſſe the Ellipſis twice (as ſomtimes it will) take that croſſing that is furtheſt from the Meridian.

Secondly, for South declinations. The work is in a manner the ſame: only you muſt note that the threed will croſſe the Ellipſis twice, and you are in this caſe to take that croſſing which is neereſt to the Meridian.

By ſuppoſing the Altitude to be 00, that is, by laying the Ellipſis upon the line T V, and uſing the Declination as before, you may finde both the Amplitude and Aſcenſionall difference as before, and what elſe doth thereon depend.

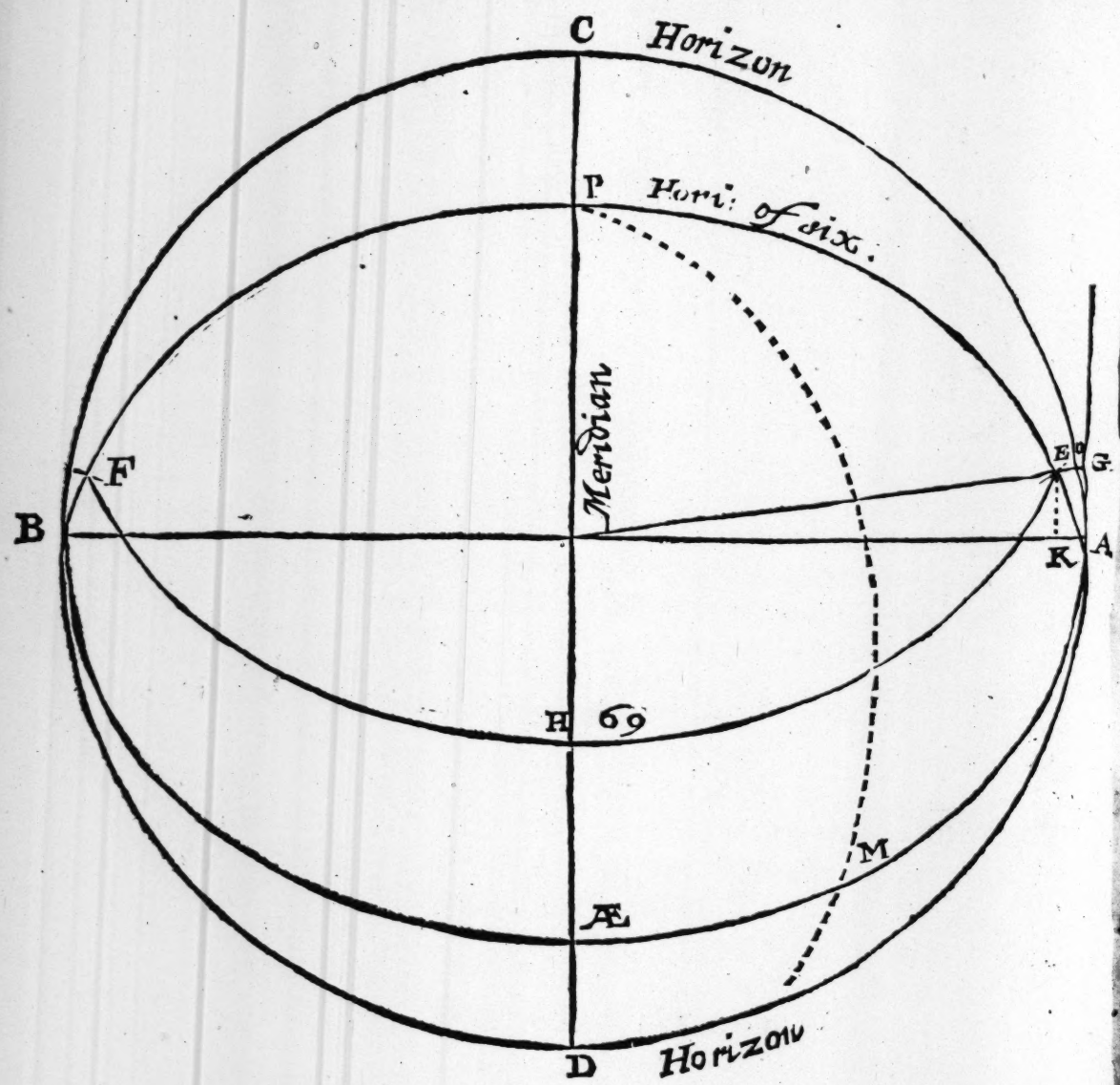
But becauſe theſe things being done neer the Horizon, will not prove good, eſpecially when the Declination is little from the Equinoctiall: and becauſe the work at the beſt is but troubleſome, I ſhall here break off, ſuppoſing that I have already written too much.

A

A DEMONSTRATION of the Ellipticall Diall upon an Horizontall Plain: ſhewing the reaſon why the ſame *Diall, by an upright Index ſhould ſhew the true Houre.*

THE reaſon is principally deduced from the Sphere it ſelf: and ſecondly, from the *Orthographicall* Projection of the Sphere upon the plain of the Horizon; which as it doth repreſent the Sphere it ſelfe, ſo it doth perform the ſame concluſions with the like certainty that the Sphere doth; and that upon this generall ground, that looke what Circles, and in what parts they cut each other upon the former, the ſame Circles and the ſame parts of thoſe Circles do upon this latter cut each other in the ſame manner. I ſhall here take for granted, that the Projecture is (for truth) in all reſpects anſwerable to the Sphere it ſelfe, which is abundantly made good by thoſe that have treated upon this ſubject. Then from thls Projection I ſhall ſhew how the Ellipticall Diall upon the Horizon muſt be of the ſame truth with it. And therefore theſe things following muſt be conſidered, as ſo many Lemmaes to prove what is here required.

Note,



Note, that in no form of Projection beſides the Orthographicall, this kinde of Diall can be true; that is, that no figure but an Ellipſis will do it, nor yet all Ellipſes, or Ellipſes divided into all ſo[illegible]ns, as in ſome Projections they

are, when one halfe or 180 *gr.* on one ſide, are greater than the other halfe or 180 *gr.* on the other ſide: theſe will not do here, but only ſuch as whoſe extream Diameters are the ſixes and twelves, that is, ſuch as are produced by infinite Orthographicall Projection.

LEMMA I.

First, *The Equinoctiall Circle, and all the Parallels of Declination, are projected upon the plain of the Horizon into like Ellipſes. And that they are all of them divided (by the Meridians) alike or proportionally one to the other.*

The reaſon of this may be conceived upon this ground. Since the Equinoctiall and all the Parallels are Circles of a juſt parallel ſituation one to the other (as their name imports:) therefore on what point ſoever of the horizontall Axis the eye is placed, the ſaid Circles muſt be Ellipſes (excepting only if the eye be placed upon the ſuperficies of the Sphere, for then, and only then, they will be all perfect Circles,) as all that write upon this ſubject do ſufficiently make good: and conſequently, when the eye is placed upon the ſame Axis, in an infinite diſtance, as this Projection ſuppoſeth. But the ſecond thing is more to our purpoſe, and that is, that all their degrees and quarters, and other like parts, art like and proportionall one to the other (not all the parts of one and the ſame Ellipſis are like, that is equall, one to the other, as in the Circles themſelves upon the Sphere they are, but each one of theſe Ellipſes is juſtly like any other of them, both in the whole, and likewiſe when any of the like parts of one be compared with the like parts of the other, as one quarter, &c. with another.) And the reaſon briefly is, becauſe the eye is ſuppoſed (in this Orthographical Projection)

to

toſtand in an infinite diſtance from the plain on which the projection is made; and becauſe it doeh ſtand in an infinite diſtance, therefore all theſe Circles are alike ſituated to the eye, and conſequently muſt make a like or proportionall Projection of every of thoſe parallels with their like ſituated parts. But if the eye ſhould ſtand at a finite diſtance, then theſe parallels would not have a like ſituation to the eye, neither in reſpect of diſtance, nor in reſpect of poſition, and ſo the like parts of the parallels could not be like one to the other in the Projection, becauſe of their different poſition. But in the Orthographicall Projection at an infinite diſtance all things will be alike, being alike projected from a like poſition. I ſay in this it will be ſo, and in none beſides this.

COROLLARY.

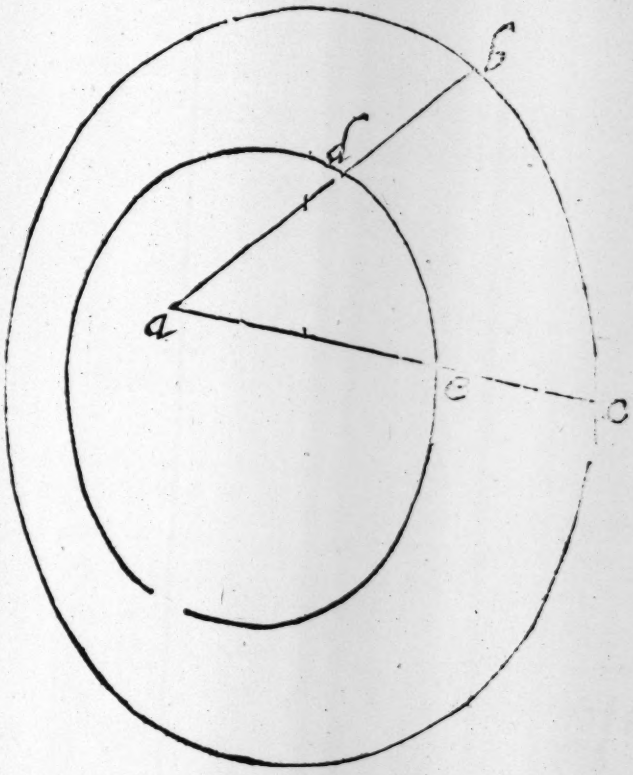
Whence will follow: *That the Equinoctiall Circle, or Ellipſis rather, may repreſent both it ſelfe, and likewiſe any other of the Parallels, if it be ſo contrived to ſtand from the Zenith point, as that it may have a proportionall ſituation from it, ſuiting with the poſition of any other Parallel which it is to repreſent.* And this is the main ground upon which this Diall will be proved to be true.

LEMMA II.

Secondly, *Any two like plain Figures may be alike ſituated to any point aſſigned; ſo as that from that point any two right lines being drawn infinitely, ſhall cut proportionall parts from thoſe two like figures.*

This

This is generall to all like figures, whether they be two or more; plain or ſolid: but for our purpoſe it will be enough to ſhew it to be true in like Ellipſes. One way for the making of one Ellipſis like to another, is by aſſuming of any point, as *a* in the greater Ellipſis, and from thence drawing as many lines as you wil, as *a b*, *a c*, you muſt divide them into proportionall parts at *d* & *e*, that as *a b* to *a d*; ſo *a c* to *a e*: & then through thoſe points the leſſer Ellipſis may be drawn, which muſt be like to the greater, and alike ſituated to the point *a*, becauſe all thoſe lines are proportionall, and the ſubtenſes *b c*, *d e*, will likewiſe be parallel and proportionall. And if the lines *a b*, *a c*, had been augmented proportionally (as here they were diminiſhed) there would have been a greater Ellipſis deſcribed, like to the other.



COROLLARY.

Hence will follow. *That if the centers of two like Ellipſes be laid upon one line, as upon one of their common Diameters, and from any point aſſigned (unto which they are to be alike ſituated) there be an infinite line drawn to any point of one of the Ellipſes, and the like point of the other Ellipſis be brought to that infinite line (the center of it ſtill keeping upon the common Diameter,) thoſe Ellipſes in that ſituation ſhall ſtand alike poſited to the aſſigned point.*

Becauſe there are two lines (the common diameter and the infinite line) that from the point aſſigned do cut like parts of both Ellipſes. The common diameter makes them alike ſituate in reſpect of one dimenſion (ſuppoſe the length) of the *locus planus* whereon they lie, and the infinite line limits them in reſpect of the other dimenſion (ſuppoſe the breadth) of the ſame *locus planus*. So that they are quite limited in reſpect of their like ſituation to the point, and can (in this reſpect) lie in no other place for this individuall poſition.

LEMMA III.

Thirdly, *All the Azimnths of the Horizon are (in this Orthographicall Projection) caſt into ſtreight lines meeting all in the Zenith point.*

The reaſon is, becauſe all theſe Circles do croſſe each other upon the Axis of the Horizon (or upon the Zenith line,) upon which line the eye is imagined to be placed at an infinite diſtance. Therefore they all (that is, the plains of them

them infinitely continued) do croſſe through the eye, and conſequently muſt all be projected into ſtreight lines. And their concourſe being upon the Zenith line, and the ſame Zenith line comming into the eye, the ſaid whole line, and their whole concourſe will be caſt or reſolved into one ſingle point, anſwering to the Zenith point of the Sphere.

The application of theſe things to the purpoſe intended.

First, In the Projection it ſelfe we are to conſider theſe things.

If it be furniſhed with parallels and houres, as the manner is, and laid horizontally with the Meridian line of it juſt North and South: and if further, there be an upright Index ſet in the Zenith point at Z, then ſhall the ſhadow of that erect Index repreſent the Azimuth in which the Sun is, and if you note where it cuts the Parallel wherein the Sun (for that day) is, the ſame ſhadow will ſhew (among the houres of that parallel) the time of the day.

This concluſion is true upon any Horizontal Projection (the Stereographicall as well as the Orthographicall) for the ſtreight lines or Azimuths whether ſhadow or Index comming from the Zenith, and cutting through any houre in any parallel, doth ſhew the Azimuth in which the Sun muſt be at that houre for the day of that parallel.

And further, becauſe all the Projection is made upon the plain of the Horizon (which therefore muſt be the fundamentall Circle of the Projection, and) which for that cauſe is, and muſt be (as all fundamental Circles of any Projection are) equally divided; Therefore an upright Index ſtanding

in Z the center of it, and ſo anſwering to the Zenith line of the Sphere, and the degrees of the Horizontall Circle anſwering to the degrees of the Horizon in the Sphere. I ſay the ſhadow of that Index doth really ſhew the true Azimuths of the Sun, or the true angles of poſition that the Sun at any time maketh with the Meridian line. And further, the ſame ſhadow or Azimuth where it croſſeth the Parallel of the day (which Parallel is divided into its proper parts, like to the parts of the Equinoctiall, by the Meridian Circles iſſuing out of the Poles) it notes out alſo the houre of the day.

So that the Projection made in this manner with an upright Index and divided Parallels, will (by the ſhadow of that Index) ſhew the true houre of the day upon that parallel that is proper for the day, if the Meridian of the Projection lie in the true Meridian of the Horizon.

The next thing to be ſhewed, is how the Elliptical Equinoctiall may ſupply the uſe of all the Parallels.

That is to ſay, How the Equinoctiall, being made movable, and the Index ſtanding alwayes ſtill, may be fitted to repreſent any of the Suns parallels. And becauſe (as was ſaid before) it is every way like to each of the Parallels, it will therefore be only required to give ſome rule how the ſaid Equinoctiall may be at any time placed in a like poſition to the *Z*enith point at *Z*, that any parallel hath to the ſame point, ſo as that any right line (or Azimuth) being drawn from thence may cut a like part or point in the Equinoctiall that it doth in the Parallel.

Let the Parallel be H E, I would remove the Equinoctiall Æ A ſo, as that it might have a like poſition to the point *Z*, that the Parallel H E hath.

By the *Corollary* of the firſt *Lemma*, it may repreſent it. By the *Corollary* of the ſecond *Lemma*, the way of it will be eaſie.

eaſie. For firſt, the two Ellipſes H E and Æ A, have their centers upon the Meridian line Æ H Z P, as upon one of their common Diameters. Secondly, the Parallel H E cuts the ſix a clock Circle, or Meridian P E A, in the point E, making E A equall in radiall degrees to H Æ (for the Parallel is every where equidiſtant to the Equator, and the Meridional Arks, therefore, intercepted between them, ſuch as are E A and H Æ, muſt be equall.) So that E A is the Declination of that Parallel from the Equinoctiall. If therefore the line (or Azimuth) Z E be drawn infinitely through the point of 6 in the Parallel, or through the Declination (of that Parallel) counted in the Circle of ſix; and then the Equinoctiall (ſtill keeping its center upon the common Diameter Æ P) be ſlipped up till the point A thereof do concur with the infinite line (drawn before) at G; in thus doing, I ſay that the Equinoctiall is in a like ſituation to the point Z, that the Parallel H E is in, to the ſame point. And conſequently, that any right line (or Azimuth) from Z, will cut the ſame (rather like) parts in one that it doth in the other. As by the *Corollary* of the ſecond *Lemma* will appear.

The next thing to be enquired is, what the line A G *is, or how it muſt be found and eſtimated.*

For this purpoſe, conſider, that Z P E and Z C O are two Triangles rectangled at P and C, and having a common angle at Z; therefore, As Z P Co-ſine of the Latitude, to Z C the Radius; So P E, the Co-tangent of the Declination, to the Tangent of C O. Or, As the Radius Z C, to the Co-ſine of the Latitude Z P; ſo is the Tangent of E A, the Parallels Declination, to the Tangent of A O, that is, to the line A G, which is the Tangent of A O, becauſe the arke A O is expreſſed in its full quantity; without any enlarging or fore-ſhortning, and the right line A G ſtands

to

to it as a Tangent thereof, ſtanding at the end of the Radius Z A. Now conſider, that if Z C be conſidered as Radius, then muſt the Tangent of E A be the Tangent of the Parellels declination, eſtimated to the ſame Radius. And becauſe Z P is in the ſelfe ſame proportion to A C, therefore: If Z P (the Co-ſine of the Latitude) be eſtimated for a Radius, then muſt A G be eſteemed as the Tangent (of this Parallels declination) to the ſaid Radius Z P. And hence it will follow that

If *Z* P the Co-ſine of the Latitude [being taken (as that Co-ſine) to the Radius *Z* C or *Z A*, which is the longer Radius of the Ellipticall Equinoctiall] be counted as a Radius or Tangent of 45 *gr.* and ſo be divided and continued as occaſion ſhall be, It is to be noted I ſay, That this Scale thus limited will be a right Scale for the requiſite motion of the Ellipticall Equinoctiall to ſuch a poſition in reſpect of the Zenith point, as that it may repreſent any parallel, whoſe Declination is known, if it be removed to the ſame Declination counted upon that Scale. And being ſet in that like poſture, any Azimuth or ſhadow of the upright Index that would paſſe through any houre point of the Parallel, will alſo paſſe through the ſame point of the Equinoctiall, and ſo this one may ſerve for them all.

This gives the reaſon of making the Zodiac or Annuall Scale, mentioned in the former Treatiſe, I ſay it gives the reaſon of the ſecond way mentioned for leſſer Latitudes. For if either the Signes of the Zodiac, or the moneths of the year be put in according to their declinations taken in this Scale,

Scale, it will be all one to ſet your Ellipſis to the Signe or Moneth, that it is to ſet it to the Declination, ſince they are made one to anſwer to the other.

Then for the firſt way for greater Latitudes: becauſe,

As the Co-ſine of the Latitnde,
Is to the Sine of the Latitude;
So the Radius, (or Tangent of 45 *gr.*)
To the Tangent of the Latitude.

You ſee that if you divide the Co-ſine of your Latitude into 45 Tangents; or the Sine of your Latitude into the Tangent of your Latitude, the Scale will be all one according to the former proportion.

What is before ſpoken of North Parallels of Declination, is the ſame in South alſo, and one Scale (for the kinde of it) ſerves both; only in North Declinations the Equinoctiall goes neerer to the Zenith point, in South it goes further of.

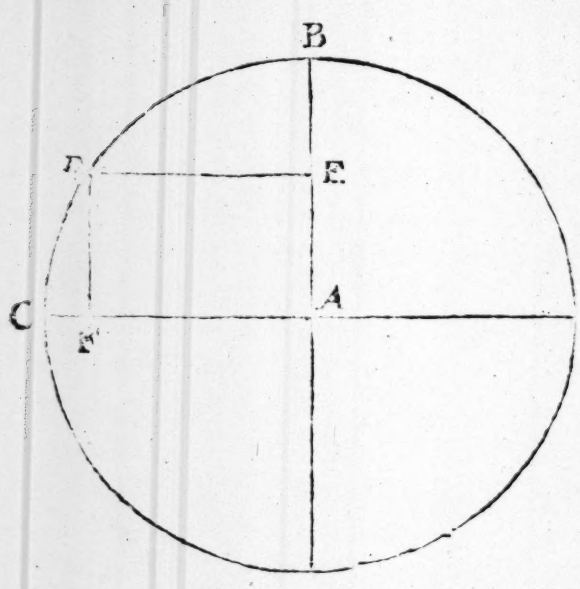
All other Scales annexed to the Ellipſis have their dependance wholly upon this Scale of Declinations, and will not need any further explication in this place.

Then again, it matters not where the little Scale or Zodiac ſtands, ſo that it give the juſt quantity of removall for the Equinoctiall Ellipſis.

And ſo alſo, it is no matter whether the Index move, and the Equinoctiall ſtand, or contrarily: It is only required that their ſituation be ſuch as may make the foot of the Index ſtand in a proportionall poſition to the ſtation of the Parallel, as was formerly ſhewed.

Further. For the circular year or Zodiac, the ground of it is thus. The Circle is ſuppoſed to be divided into equall parts

parts or degrees: and so every Sine (as is D F) is a proper Sine to any arke (as D C) to which it is annexed. Again,



A B in another consideration is to be esteemed (as formerly for the Semidiameter of the Circle, so now again) for the Tangent of $23\frac{1}{2}$ degrees, whence this proportion will stand:

As the Radius A B,
Is to the Sine F D;
So the same A B, tangent of $23\frac{1}{2}$,
To the Tangent A E.

Which is the Tanget belonging to the Right Ascension C D.

[Because in the Sphere,
As the Radius,
To the Sine of any Right Ascension,
So the Tangent of $23\frac{1}{2}$
To the Tangent of the Declination answering to that Right Ascension.]

If therefore you have the Right Ascension belonging to any day, and put it into the Circle of equall degrees, as C D here is, the Sine of that Right Ascension, *viz.* F D, will be equall to A E the Tangent belonging to that Right Ascension, if B A be taken for the Tangent of $23\frac{1}{2}$ *gr.* So that this way of putting in Moneths and Signes is the same in effect

effect with the former Zodiac or Annuall courſe of the Sun.

Thus far for demonſtration of what was hard in the firſt Section, *Pag.* 8, *&c.* concerning Horizontall plains.

What is added more in the firſt Section of framing it to other plains that are direct, is the ſame with this. For there is no difference but only in the latitude of the plain, which is no reall diſcrepance from the former, they both going upon one ground, and therefore no more to be ſaid here of ſuch plains.

Sect. 2. *Pag.* 22, *&c.*

Of framing it to Declining Plains.

DEclining plains, if they had their proper houres upon them, would alſo (in this Elliptical reſpect) be the ſame with the former direct, or Horizontall plains. The diſtinction is, becauſe they are made to another Meridian than is their own, that is, to the Meridian of the place, and all the account of houres is deduced from it. The difference therefore of theſe from the former, is only this, that the houres in the Ellipſis are not evenly fitted to the quarters or diameters of the Ellipſis, but fall to ſtand as caſually they may. Now if in the former caſe of Horizontall plains, you do but ſuppoſe the Equinoctiall and Parallels to be divided from any caſuall Meridian as P M (not P Æ) into houres and parts, then will follow ſtill the ſame things in ſubſtance that was before. Namely, That if the Equinoctiall Circle be removed according to A G (which

muſt be ſuppoſed to be ſuited to the Latitude of the place as well as to the Suns parallel of declination) with thoſe diviſions now ſpoken of, then ſtill, when the Equinoctiall by that motion hath got a like ſituation to the Parallel, the parts of one will be anſwerable to the parts of the other, in reſpect of the ſhadows or Azimuths that are caſt from the Zenith point and upright Index ſtanding in it at *Z*. So that even in theſe plains alſo, the ſame houre will be ſhewed by the Equinoctiall that would be by the Parallel. And ſo the ground is (in theſe) like (rather the ſame) in ſubſtance with the former direct plains. So much of theſe.

Sect. 3. *Pag.* 29, *&c.*

THat pricking down of the Horizontall Diall mentioned in this Section, is the pricking down of the Equinoctiall with its houres or parts, juſt as the Orthographicall Projection it ſelfe hath them. The firſt Table ſhews what Angles or upon what Azimuths from the Meridian every houre point lies. The ſecond gives the Altitudes, or rather the diſtances of the ſame houre points from the *Z*enith, And therefore no more will be required of this.

The fourth *Section* requires no explication nor Demonſtration.

Sect. 5. *Pag.* 37, *&c.*

FOr the varieties it muſt be known, that the ſubſtance is the ſame with that which went before, which being well underſtood will give light enough to this.

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But in this *Section* there is mention made of a Circle (inſteed of the Horizontall Ellipſis) elevated to the height of the Equinoctiall. The reaſon of that will beſt be ſeen out of the Sphere it ſelfe, For there we know, that the Equinoctiall and all the Parallels to it are both equally divided, and equally elevated, and ſo being all alike, the Equinoctiall may ſupply the room of each and all of them. Only it muſt be required (whether the Index move toward the Circle, or the Circle towards it) that this motion (if the Zodiac be upon the Horizontall plain) be limited by an Horizontall Zodiac, ſuch as was uſed for the Ellipſis upon any plain, (which plain, what ever it be, I now count as an Horizontall plain.) But if the Index be made to move upon the Equinoctiall (which though it do, yet it muſt ſtill lie in the Zenith line, not perpendicular to the circular plain, but making an angle with it equall to the Latitude of the place, and not the Latitude of the plain.) If, I ſay, the Index be made to move upon the Equinoctiall plain, then muſt a new Scale be made like to that upon the Horizontal plain, but ſomewhat larger; that is, it muſt be augmented ſo as that the parts and whole of the Horizontall Scale, to the parts and whole of this Equinoctiall Scale; muſt be as the Radius, to the Co-ſecant of the Latitude. Or thus. Becauſe, As the Radius, to the Co-ſecant of the Latitude; ſo the Sine of the Latitude to the Radius: and ſo again, the Co-ſine of the Latitude, to the Co-tangent of the Latitude. Therefore, whereas on the Horizontall plain (for the Ellipſis thereon deſcribed) you looke the Co-ſine of your Latitude, and make it a Radius or Tangent of 45 *gr.* you muſt in this take the Co-tangent of your Latitude, and make it a Radius or Decimall Scale; and by it you may put on the Zodiac or moneths as was preſcribed before. This Co-ſine mentioned

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before was taken to the greater Radius, of the Ellipſis, and ſo this Co-tangent here mentioned muſt be taken to the (ſame greater Radius of the Ellipſis, if the Ellipſis were here uſed, or to the) Radius of the Equinoctiall Circle, whoſe Radius muſt be conceived to be the ſame with the greater Radius of the Ellipſis. For from this Circle projected Orthographically (that is, by perpendiculars let fall from the Periphery to the ſubjacent plain) is the Ellipſis deduced, and from that Ellipſis (again) is this Circle raiſed or reſtored. And ſo the reaſon of this Circular Diall with an upright Index will be underſtood well enough.

Then whereas it is ſaid that it makes no matter which way this Circle be raiſed, that is, whether toward North or South, there is no difficulty in this, for which way ſoever it is turned, if the plain and center of it lie in a juſt diſtance from the Index or Zenith line, the ſame Index muſt ſhew the ſame point or houre, becauſe in both wayes they are ſituated from it upon the ſame Coaſt.

Sect. 6. *Pag.* 47, *&c.*

THat which is here done will not be difficult, if it be conſidered that what is aimed at, hath relation to *Stofflerius* Aſtrolabe: and that here one Ellipſis muſt ſerve to repreſent every Almicantar. I purpoſe not to repeat any thing that is before ſaid: and the rather becauſe this Structure will not be ſo expedient and ready in ſome uſes as could be wiſhed. They that deſire the reaſon of it, may fetch it out of this that hath been already ſaid: which may be done without any great labour.

SECT.

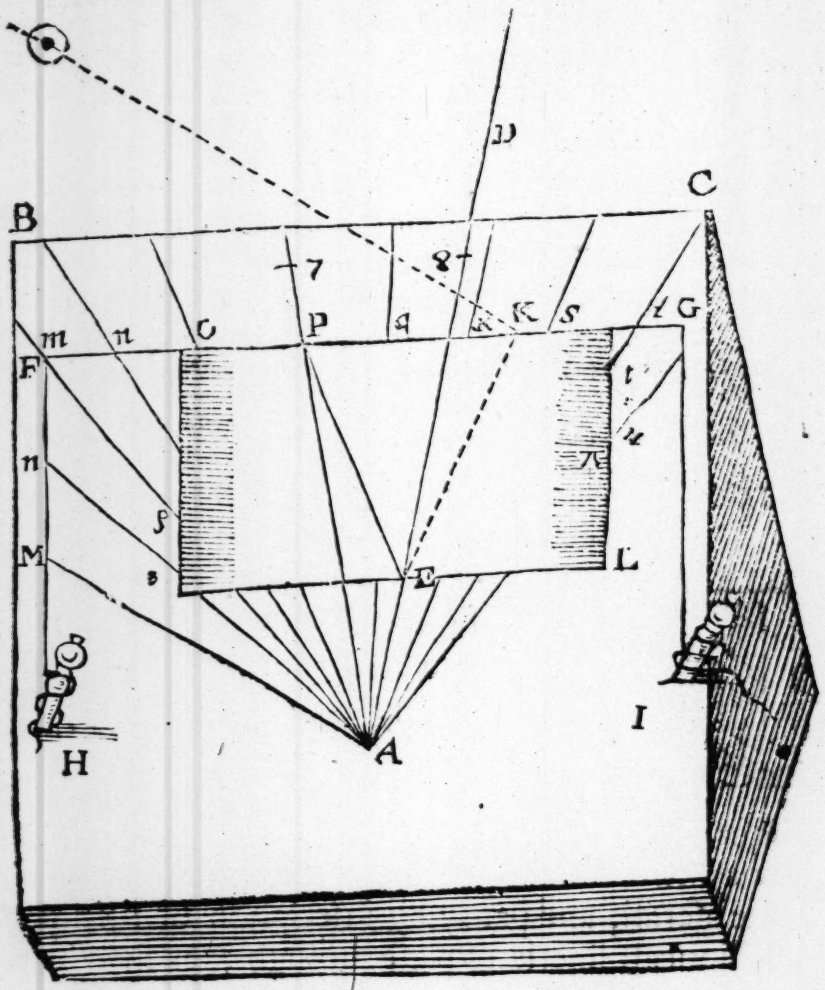
SECT. VII.

1. *How to draw and divide the Ellipſis upon any Plain, to an Index that ſtands upright (not to the Plain, but) to the Zenith line of the place, or perpendicular to the plain of the Horizon.*

THis may be done artificially by calculation, or by a lineary way, but not without too much trouble and incumberance, which would deter any man quite from putting it in practiſe. I ſhall therefore let that way alone, and fall upon another more feaſible and delightfull.

The way that I intend, is partly by projection of ſuch lines as are uſefull, and partly by inſcription of ſuch points as the Ellipticall line is to paſſe through, as ſhall be ſeen hereafter. And therefere we ſhall not need to looke after any poſition of the plain in reſpect of declination or leaning.

But firſt in generall note thus much; that the Ellipticall Diall cannot poſſibly be drawn upon any plain that lies parallel to the Index. And conſequently to theſe upright Indexes there can no ſuch Diall be made upon any upright plain. And therefore again to ſuch an Index, it is requiſite that the plain make ſome kinde of angle in reſpect of Re-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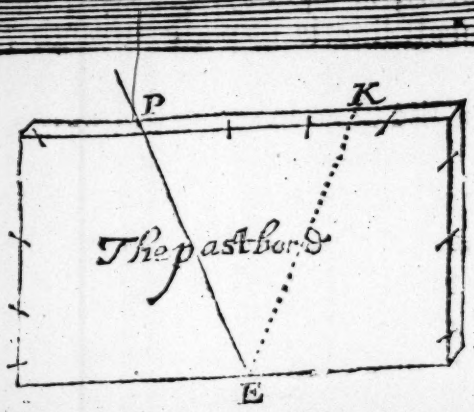
P
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The past-bord
E

Reclination or Inclination from the Zenith line towards the Horizon, which poſition (notwithſtanding) we ſhall have nothing to do withall in this way of working.

2. *The manner of the work.*

1. LEt the plain be A B C, and the upright Index A D. Firſt then, aſſume any point in the Index as at E, and from thence (by the projecting Quadrant, or ſome Levell) caſt an Horizontall levell line as F G upon the plain; or if it cannot be caſt upon the plain it ſelfe, ſet any board (for a time) that may receive it; lying in the ſame Levell with the aſſigned point at E. And further, the ſame Horizontall line muſt be continued and returned about the point E, by help of threeds ſtretched out from ſome points or other of the Horizontall line before drawn, as from F or G, unto two ſupporters ſet up (for a while) for this purpoſe (either upon the plain or otherwiſe neer to it) as is to be ſeen at H and I: ſo that now the points H F G I are all in one and the ſame Horizontall levell to one another, and likewiſe to the firſt point of the Index aſſumed at E.

2. At ſome convenient time of the day, when the Azimuth may be found diſtinctly, obſerve where the ſhadow of the Index cutteth the Horizontall line, ſuppoſe at K, and there make a mark, and immediately take the Suns Altitude.

3. By the Suns Altitude obſerved, compute what Azimuth the Sun was then in, which will tell you what Azimuth the obſerved point K (in the Horizontall line) doth repreſent.

4. Take a Paſtboard as E L, and fit it to the Horizontall line

line of the plain F G, and to the aſſumed center at E: and applying it to its proper place (as in the figure is repreſented) draw a line from the point K to the center E, quite over the paſtboard. And then knowing what Azimuth it is, you may (from it) ſet off the Meridian in the true Coaſt of it, ſuch as will be anſwerable to the heavens, which Meridian line ſuppoſe to be P E upon the Paſtboard.

5. You are next of all, from this Meridian line P E, to ſet off all the other houres of an Horizontall Diall (not the common Horizontall Diall, but) according to ſuch numbers or arks as are expreſſed in the Table of Angles, *Pag. 29.*) And when this is done upon the Paſtboard, as you ſee done at o P *q* κ *s t u*: Then,

6. Apply the Paſtboard to its former poſition upon the plain, and from the center E project the houres from the Paſtboard to the Horizontall line and threeds. And then taking away your Paſtboard, you may draw lines from A to ſuch points as are in the Horizontall line it ſelfe, as A o, A *p*, A *q*, A κ, A *s*, A *t*, A *u*. And for the others that ſtand not upon the Horizontall line of the plain, but upon the threeds which are ſeparate from the plain (ſuch as are ε ρ π) you may project them by the Index A D, repoſing the ſame upon the ſaid points (ε ρ π) of the threed; and marking where the ſhadow or appearance of the threed traceth the plain, there draw the lines A *m*, A *n*, A *u*. And ſo all the lines (that the plain is capable of) may be drawn. And it is to be noted, that theſe lines ſo drawn are not ſuch houre lines as uſually are upon other Dials, but they are thoſe Azimuth lines in which the Sun is at every houre of the Equinoctiall Circle. So the houres and quarters may be put in by the Table, *Pag. 29*, and the Column of Angles in the ſame Table.

7. Looke

7. Looke again into the Table *Pag. 29*, for the Column of Altitudes; for by that muſt the Ellipſis it ſelfe be deſcribed, for the former Azimuthall-houre lines will give it the true diviſions into its requiſite parts. The manner of the diviſion is this. Make a Scale of 90 right Sines, but number them verſedly, as is here expreſſed. And let the Scale be of a fit bigneſſe for your plain, which your own judgement muſt direct you to do. Out of this Scale (ſetting alwayes one foot of your Compaſſes in the point of 90) take ſuch Altitudes as are (in the Table) appropriated to every houre, and put them into thoſe ſeverall houres in this wiſe. Suppoſe the altitude for 12 a clock were to be put in, which altitude is 38 *gr.* 30 *min.* with my Compaſſes I take (in this Scale of Sines) from 90 to 38 *gr.* 30 *min.* and one foot of that length I put into the line of 12, namely P A upon the plain, and (alwayes keeping it upon ſome part of that line) I remove it thereon, neerer to, or further from the center A, till the other foot of the Compaſſes being turned about will juſtly touch the edge (or fiduciall line) of the Index. Then I diligently obſerve where, or in what point of the line P A the firſt foot of my Compaſſes ſtayeth, for that is the point through which the Ellipſis muſt paſſe upon the houre-line of 12. So for any other houre (and the intermediate quarters) taking their altitudes, (ſet down in the Table) out of the ſame Scale of Sines, and inſerting them in the ſame manner as was ſhewed before, you ſhall finde all the points (for every houre and quarter) through which the Ellipſis is to be drawn. Through theſe points therefore you muſt draw it carefully, as one continued line, without any breaches or angles in it.

3. *Concerning the motion that is to be made either by the Index, or by the Ellipsis it selfe.*

THe motion must be made according to the 12 a clock line, which is alwayes the proper Meridian to the Index or Zenith line. That is, the removall or sliding must be either in the Meridian it selfe, or else parallel to it.

Now if the Diall it selfe be made to slide upon the plain, that is, if the Ellipsis be to be described upon another plate that shall slip over the former plain, then must this plate be first of all laid fast upon the plain, and the houres and Elliptical line must be described thereon in the same manner that was shewed before. And this plate must move in the Meridian line, that is, the 12 a clock line of the plate (being imagined to be continued forth right) must move through the fiduciall edge of the Index.

And so again, If the Diall be drawn upon the plain it self, and the Index be made to move (the Diall it selfe standing still) then must care be had that the fiduciall edge of the Index do precisely move in the Meridian or 12 a clock line, and that the same Index move alwayes precisely upright in the Zenith line.

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4. *Concerning the Place of the Suns Annuall course or Zodiac.*

THe place of it may bè best upon the plain. It must stand (if it be inscribed into a streight line) parallel to the line of 12, and needs not to be in or upon the said line. The mover (whether plate or Index) must have another peculiar

Index

Index in it, called here the Zodiacall Index, by which it is to be rectified according to the time of the year, If the Zodiac be put into a Circle (as is mentioned *Pag. 15.*) then that Diameter (of the Annuall Circle) which passeth from Tropick to Tropick, must be either in or parallel to the line of 12.

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5. *Of what limitation or length the Zodiac must be, and how to be described, and where to be set.*

IT must be regulated by the former Scale of Sines mentioned *Pag. 73.* For you may take from 90 (in that Scale) to the number of the Latitude of your place (not complement as that Scale is numbered) and count that length as a new Radius. Unto this new Radius finde the Secant of the Meridians inclination (which what it is shall be presently shewed in the 6 *Proposition* following) and then make this Secant to be a Tangent of 45 *gr.* and out of that Scale of Tangents take 23½ *gr.* for that length being set both wayes from the Equinoctiall, will give the length of the Zodiac (in a streight line, or the Diameter of the Zodiac put into a Circle:) this work is to be understood for the describing of the Zodiacall Scale upon the plain it selfe. But first, you are to pitch the Equinoctials place, which is that place only upon which the Zodiacall Index lyeth, when the mover (whether plate or Index) is placed in the same position that it had when the Ellipticall line was described. Now when this Tangent of 45 *gr.* is thus found, you may take the Declinations (in the Tables of the 4 and 5 *Pages:*) out of it, and so prick on the Suns yearly course. Or else make the

forementioned Secant a Decimall Scale, and out of it take the Tangents noted in the Tables *Pag. 6, 7.* So ſhall you make the ſame Annuall courſe of the Sun that was produced the former way.

Note, that if the Index be made to move, it is not neceſſary that it ſhould move upon or parallel to the ſuperficies of the plain, but may be made to move either horizontall, or at any other inclination: only the fiduciall edge muſt neceſſarily be made to move in the very Meridian line, and muſt alſo be (in all motions) alwayes upright, or in the Zenith line of the place; and therefore muſt ſlide juſt under the Meridian line.

Note alſo, That the *Zodiac* though it be not neceſſarily confined to be ſet upon the ſuperficies of the plain, yet it will be moſt conveniently limited thereunto.

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6. What the Meridians inclination meaneth, and how to finde the quantity of it.

BY the Meridians inclination is meant what angle the ſame line maketh with the plain of the Horizon, and in the former figure *Pag. 70.* it is expreſſed by the complement of the angle D A P, or the exceſſe of it. To finde it, you may either apply the edge of an Inclinatorie ſquare to the ſaid Meridian line, and then the threed (being drawn perpendicularly down by the plummet) will ſhew the ſaid elevation (or inclination) of the Meridian line above the Horizon, in the degrees of the limbe, if the ſame degrees be taken to the threed from that ſide of the Square that ſtands perpendicularly upon the Meridian line. Or elſe another way may be by protracting or meaſuring the angle D A P, which

which is the complement of the former required inclination. It may be done thus. Set one foot of your Compasses at A, and let the other foot be extended to any point of the Index, suppose to 8, then measure the same length A 8 upon the Meridian line, which let be A 7, and to this length fit your line of Chords (upon the Sector, or some like opening Scale of Chords.) Then take the length from 7 to 8, and measure the same upon your Scale of Chords, so shall you finde the quantity of the angle D A P, whose complement (or excesse) is the inclination, or elevation, or depression of the Meridian, which is here required.

7. *Other things to be noted concerning the Zodiacall Scale.*

1. IF the Diall be described upon an irregular superficies, such as is not flat but writhen (as by this course it may very well be) then it is most convenient that the former Scale be set in some other place, and not upon the superficies whereon the Ellipsis is described. It may be contrived two wayes.

First, If the Diall superficies (how irregular soever it be on that face whereon the houres are inserted) be flat at the bottome, and be made to move (the Index standing still) upon some other plain below it) then the best way will be to make the *Zodiacall* Index upon the moving bottome of it, and to describe the *Zodiac* upon the other plain upon which the motion is made. And to do this aright, you must project the Meridian line upon that nether plain, and finde out the inclination of it, and so finde the Scale by the Secant of that inclination, just as you were before directed. And so this work will be compleat. The

The motion of dials unequall Superficies muſt be in or parallel to this laſt projected Meridian line, alwayes ſo as that the Meridian of the Diall muſt paſſe through the fiduciall edge of the Index.

Secondly, If the Index be made to move (the Diall ſtanding ſtill) and that the Diall be upon ſome unequall ſuperficies, ſuch as is unfit to receive the Zodiac, then the foot of the Index may have it inſcribed upon it. Now in this caſe of unequall Superficies, it is ſuppoſed that this foot of the Index cannot move parallel to that uneven Superficies, but muſt move ſtreight forward in ſome right line, juſt along with the Meridian line. In this caſe you muſt finde the inclination of the foot of the Index to the Horizon, that is, what inclination a line drawn upon the foot of the Index, either in or parallel to the Meridian line, hath to the Horizon, which muſt be done by ſome Inclinatorie Inſtrument, or ſome ſuch way as is uſed in taking the Reclination or Inclination of Plains. And when this is done, you are to finiſh the Zodiac Scale by the Secant of that inclination, in the ſame manner as was before ſhewed. So much for this.

2. For the other Scales of the Suns Declination, Amplitude, Aſcenſionall difference, and graduall motion in the 12 Signes, they are to be done in the ſelfe ſame manner, and by the ſame Tables as before (without any difference) after that you have found your Tangent Scale or Decimall Scale out of which to deſcribe them.

8. *Another*

8. *Another Obſervation.*

ACcording to that generall obſervation *Pag. 36.* Note here; That if to an Index ſtanding in the Zenith line, a Plain be ſet in the Equinoctiall, the ſame plain ſhall have a Circular Diall upon it, equally divided. Then whether the ſaid Equinoctiall plain or the Index move, if they be made to move upon the Horizontall plain, the Zodiac for the Horizontall plain muſt ſerve. But if the upright (or Zenith line) Index be made to move upon the Equinoctiall plain, the former Horizontall Zodiac muſt be ſet upon the Equinoctiall plain, and muſt there be enlarged above the Horizontall Zodiac, that is, every part of the Horizontall Zodiac muſt be made greater upon the Equinoctiall plain in proportion as the Radius to the Co-ſecant of the Latitude. That is, the Scales that made the Horizontall, being taken as Radius, muſt now here be enlarged to be as Co-ſecant of your Latitude; and from them (ſo enlarged) muſt the parts of the Zodiac be inſcribed upon the Equinoctiall plain.

Note further. That for this Equinoctiall plain which is to deſcend downwards from South towards North, you may inſteed of it ſet another plain quite contrarily, that is, deſcending from North towards South; which will be the moſt convenient of the two, becauſe the upper face of this will give the houre all the Seaſons of the year, whereas the other will be only for Sommer upon the upper face of it, and will require an under face for Winter.

SECT.

SECT. VIII.

Hitherto of Ellipticall Dials to all Superficies whether plain or curved, whose Indexes ſtand upright in the Zenith line of the place: There now followeth ſome other directions how the ſame thing may be done to any Superficies, and to an Index ſet caſually in any poſition whatſoever. But firſt are premiſed ſome uſefull Propoſitions tending to the ſame purpoſe.

1. *An Index or ſtreight line being ſet caſually, how to finde the* $\frac{Re}{In}$*-clination and declination thereof.*

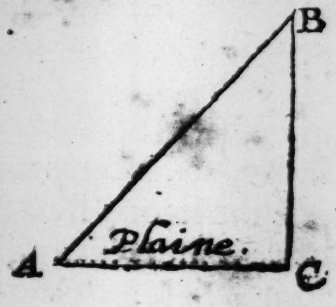
IF it ſtand upright, it is free from both thoſe accidents, and falls to be the ſame caſe with the upright Index before treated of.

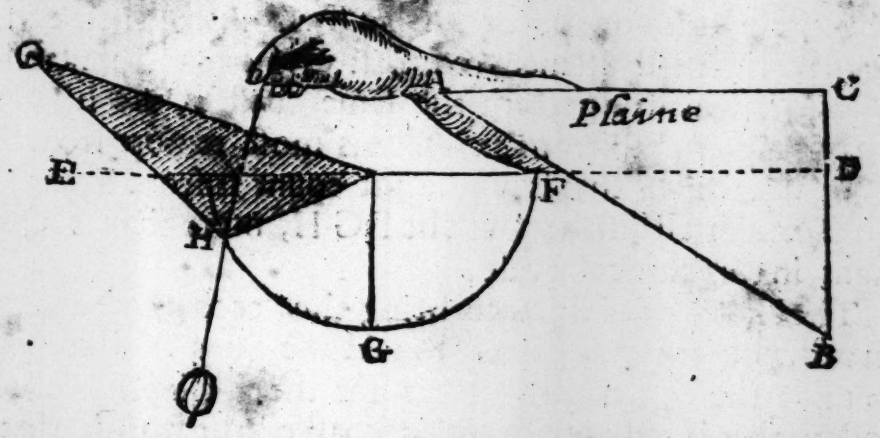
But if it lie leaning, then is it to be dealt withall in this place.

And firſt for the $\frac{re}{in}$-clination, it is beſt to be taken by ſome inclinatory (ſquare or other) Inſtrument. The manner of the work is the very ſame that is performed in

in finding the re-clination of a plain: becauſe the fiduciall edge of the Index is (here) like the Verticall line of a re-clining plain, and the application of the Square muſt here be the ſame to this edge that was there to the verticall line of the plain, and the degrees of re-clination are to be numbered in both theſe caſes alike. So that it will not be needfull here to make repetition of that which is ſo often elſwhere declared. You are here alſo to obſerve whether the re-clination be towards the North or towards the South.

Then for the declination do thus. Suppoſe the Index to be A B. From the end of it that is furtheſt from the plain, as B, let fall or raiſe the perpendicular B C, and let B C be ſome materiall object unto which the ſide of a Quadrant may be applyed. Or if they ſhould be threeds (and ſo too





weake for ſuch a purpoſe) you may extend another threed, as is D E, which may touch the two former threeds A B and C D, and ſo lie in the ſame plain with them, and then

to this threed D E apply ſome upright plain or materiall object which may ſerve the intended work.

To this new plain therefore, or to the two lines A B, C D, apply one of the ſtreight edges of a Quadrant, the limbe of it being turned alwayes towards the Sun, and obſerve the Horizontall diſtance of the Sun, as is uſually done in finding the declinations of plains. Only here take this caution, that you count not this Horizontall diſtance from that ſide of the Quadrant which is perpendicular to the plain, but from that ſide which lies in the line E D, or upon the two lines A B, B C. And further, you are alwayes to account this Horizontall diſtance from that end of the Quadrants ſide which lookes the ſame way that the point B (of the Index, which is furtheſt remote from the plain A C) doth look: as in the ſecond figure is expreſt, where the Horizontall diſtance is more than a Quadrant, it being there to be accounted from F to H. Or for more eaſie conceit, you may alwayes ſuppoſe your Quadrant in that poſture to be continued to a Semicircle, as is done in the ſecond figure: and then count your Horizontall diſtance from that term of the Semicircles Diameter which reſpecteth the ſame coaſt of the heavens with that point of the Index which is moſt remote from the plain, which is B; that is, you muſt count it from F, and ſo the Horizontall diſtance will be F G H, more than a Quadrant, in this particular caſe.

The Horizontall diſtance being thus accounted and obſerved, you are immediately to take the Suns Altitude and to finde the Azimuth. Then for the declination of the Index, that is to know into what coaſt of the world, that is into what Azimuth of the Heavens (it being continued from the plain at A infinitely forwards toward B) it would point into: I ſay to finde this, you have only the ſame work to do

which

which is usually done in finding the declinations of plains, the same work without any difference at all. And therefore I shall not here give any further directions in this particular, because I have done it often enough in other places, to which the Reader may have recourse.

And so I suppose the position of the Index in respect of $\frac{Re}{In}$-clination and declination to be fully found out, both for coast and quantity; by which two things known, we are further to enquire what Longitude from our Meridian, and what Latitude the said Index pointeth unto, which will be the next Proposition.

☞ Note, that though I call A C a plain, yet it may be any curved Superficies as well as a plain, for the Dial will be described upon one as well as the other indifferently.

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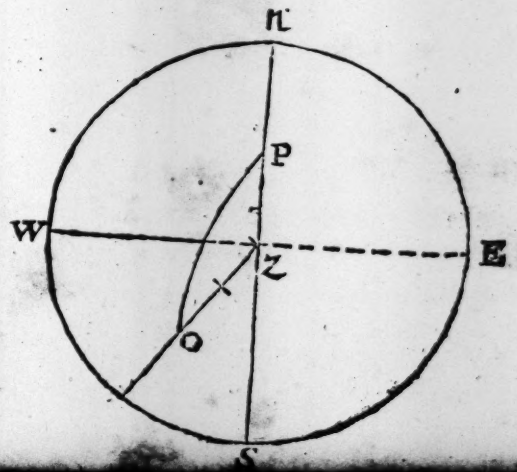
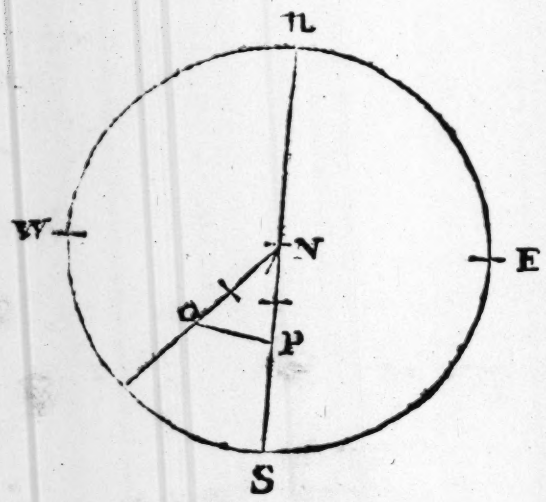
2. *By having the* $\frac{Re}{In}$*-clination and Declination of any right line, to finde the Longitude and Latitude thereof.*

THis shall not here be much spoken of: for we may suppose the Index A B in the first Figure, to point up to O in this Projectiō (wherein the Horizon is N E W S, the Zenith Z, the North Pole P) and that the reclination Z O, with the



the Declination O Z S, or O Z P be known, together with Z P the complement of the Latitude of your place, so it shall be easie thereby to finde the side O P, whose Complement is the North Latitude, or whose excesse is the South Latitude required: and the angle at P will be found also, which is the difference of Longitude sought for.

Now in the second case before given where the Index points downwards, or under the Horizon, where the plain is inclining, and so looking downward, we may shape the Projection a little otherwise, and the work then will be as easie as the former. Let ℞ E S W be the Horizon, ℞ the North, S the South, P the South Pole N the Nadir point opposite to the Zenith, O the point or place to which the Index respecteth. In the Triangle N P O, are given, N P the complement of the Latitude of the place, N O the inclination of the Index; and P N O the declination of the same Index, by which we may finde P O, whose complement is the South Latitude, or whose excesse is the North Latitude required: and the angle at P will be found, which is the difference of Longitude here sought after.



The work is easie to them that understand the like work in re-clining plains, and may be performed either by calculation, or else Instrumentally, as every one shall like best of.

of. And this is all that needs to be said of this particular.

3. *How to finde a Meridian line, and to erect a true Axis of the World from the foot of the Index.*

THe foot of the Index I call that point where the Index enters into the Diall superficies, whatsoever that superficies be, whether plain or curved. As in the two former figures may be understood by the point A.

From the foot or point at A, set some upright threed which may represent the Zenith-line of the place, as is to be seen in that Figure *Pag.* [illegible]. and is there represented by the line A D. Then one way will be to make use of some other Meridian line, observing when the Sun comes to it, and at the same moment to note out the shadow cast by the line A D, for that is the Meridian line. But this is for such superficies upon which the Sun comes at noon: and it ties a man to the Meridian moment. But without this we may (according to the four first Precepts) set off the Meridian line P E upon the Pastboard, and by the Zenith-line A D you may project it upon all objects that shall stand or be set in the way. For which purpose you must place some object upon that Coast of A D upon which any one of the Poles of the World may be projected, and also elevated above your Diall superficies. And upon this object project the Meridian neer that place whereabout you conjecture the Axis of the World will passe through. Then with your Semicircle (or projecting Quadrant rather) project the Axis of the World, as is usually done in my wayes of Dialling, and by that means you shall finde a point in the formerly projected Meridian, which

which ſhall repreſent the Pole of the World. And then further, if from the foot of the Index at A, to this Pole, you faſten a threed, the ſame threed will repreſent the true Axis of the world comming from the foot of the Index.

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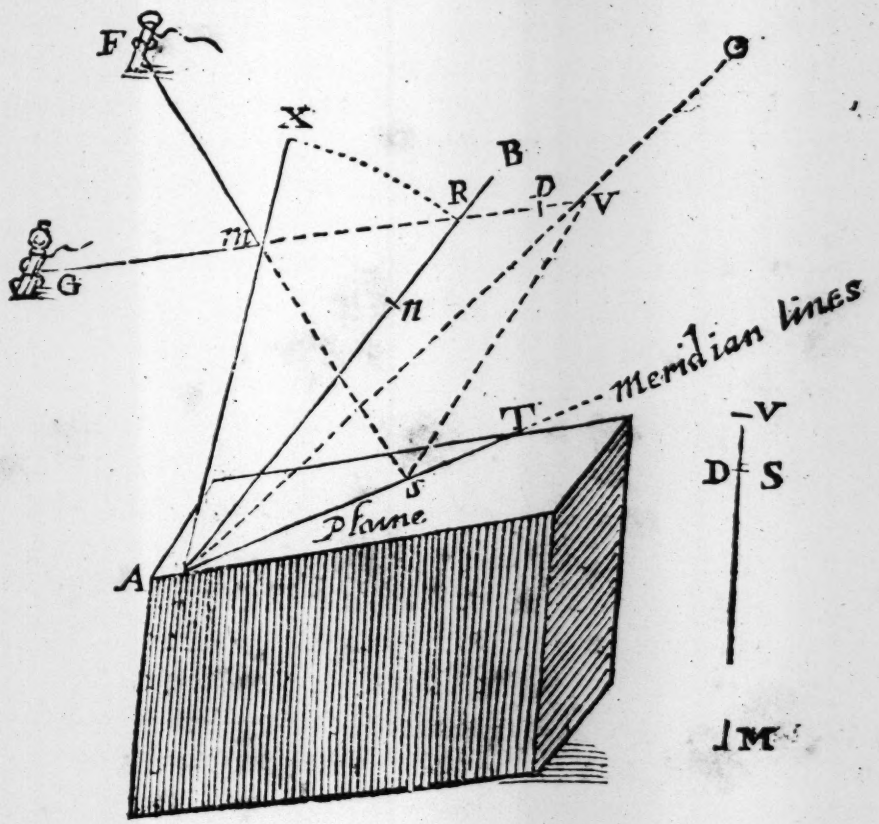
4. *Having an Axis raiſed from the foot of the Index, how to finde in what Longitude and Latitude the Index it ſelfe lyeth, by a way eaſier and differing from the former, without looking after any* re-in-*clination or declination of the ſaid Index.*

THis way will not prove (perhaps) ſo good as I expected, eſpecially in the Longitude, and therefore the former may be uſed.

The former way that I uſed was troubleſome enough for effecting of what was by it intended, which is the cauſe that I ſhall here endeavour to give another more eaſie.

Let the Diall ſuperficies be ſuppoſed to have upon it an Index, an Axis truly placed, iſſuing from the foot of the Index, with a Meridian line projected alſo to, or directly under the ſame Axis, according as was done in the work of the preceding Propoſition.

Firſt then, for the Latitude of the Index, it is but enquiring what angle is contained between the Axis and the Index, and the thing is reſolved. Now to do this, for the manner of it, we may ſuppoſe A B to be the Index, and A X to be the Axis. Opening therefore your Compaſſes to any extent, ſet one foot of it at A, and ſuppoſe the other to reach up to *m* upon the Axis, at which point *m* faſten ſome knot of threed, which may firſt be put on, and then ſlipped to the point of the Compaſſes at *m*. So again, ſet on



on the ſame extent from A to *n* upon the Index. and at *n* faſten another knot of threed. Then alſo to the ſame extent open the Radius of a line of Chords. When this is done, take the diſtance between the two knots *m* and *n*, and meaſuring it upon the ſame line of Chords, you ſhall finde what angle is contained between X A and A B. If A X therefore point from A towards the North Pole, and that X A B be leſſe than a Quadrant, then doth the complement of that angle X A B give the North Latitude whereinto the Index pointeth: but if X A B be more than a Quadrant,

then

then doth the exceſſe give that South Latitude whereinto the Index pointeth. And ſo contrarily, if A X had pointed from A towards the South Pole, then the angle X A B being leſſe than a Quadrant would give the quantity of South Latitude: but if X A B had been greater than a Quadrant, then the exceſſe would give the North Latitude into which the Index tendeth.

All the difficulty in this work is, that there is no ſtable place whereon to fix the Compaſſes for meaſuring of the diſtance between the two knots *m* and *n*: but you may hold ſomthing underneath cloſe to one of the points (without diſturbing the threeds place) on which ſetting one foot of your Compaſſes, you may meaſure the diſtance of the other point. Or elſe, becauſe it is ſuppoſed that the threed Axis A X is fixed upon ſome ſolid thing at X, you may open your Compaſſes to the Radius A X (to which alſo you are to have a Radius of Chords equall) and ſet the ſame extent from A to R upon the Index (prolonging the Index if need be by a threed till it come to be of a competent length) and there faſten a ſlipping knot. Then becauſe X is a ſtable point, you may take the extent from X (ſetting one foot of your Compaſſes in that point) to R, and meaſure the ſame upon your Scale of Chords, where it will give the former angle X A R, which is to be uſed as is ſhewed before.

There will be found other wayes to do this laſt work. So much therefore for the Latitude.

Secondly, For the Longitude of the Index, it will not be ſo eaſily had as the other was. The way that beſt likes me (amongſt many others) for the preſent, is this. By the *Precepts, Pag.* 70. you muſt make ſome obſervation of the Suns Azimuth (and ſo muſt you alſo do by the laſt precedent *Propoſition*) and you finde what Azimuth that is too.

You

You may alſo (further) project it upon your Diall ſuperficies, and then you have two Azimuths upon the ſaid ſuperficies, namely, the Meridian, and the obſerved Azimuth. You are to know yet further, what Altitudes the Equinoctiall hath upon theſe two Azimuths. And for the Meridian it is certain enough that the Altitude there, is equall to the complement of your Latitude. For the other Azimuth ſay thus.

As the Radius,
Is to the Co-tangent of your Latitude;
So is the Co-ſine of your Azimuth,
To the Tangent of the Equinoctials altitude upon that Azimuth Circle.

After this you muſt make ſome mark or knot upon your Axis A X, which ſuppoſe to be at *m*, and then with your projecting Quadrant (upon your Meridian and Azimuth) from the point *m*, ſet on the reſpective Equinoctiall Altitudes, as the manner of projecting by that Inſtrument uſeth to be.

Next, you muſt project this Equinoctiall Circle all over the Diall-ſuperficies (and upon ſome other objects where need ſhall be,) ſuppoſe it here to be the line S V.

And furthermore, you are to proiect the Axis A X, and the Index A B, one upon the other, and to obſerve the line that they both (in that poſition) do make upon the Diall-ſuperficies, and other objects if need be. I ſay you muſt, firſt, principally obſerve this line, for it is the proper Meridian line to the Index or Zenith line A B, becauſe it paſſeth (*quoad ſuperficiem*) through both the Axis of the world and the Zenith line. Suppoſe it in the former plain to be A ⊙. And ſecondly you muſt note the interſection that this line makes with the Equinoctiall line which was now pro-

jected, which we may imagine to be at V, upon some object laid in the way of purpose. And so also you must (thirdly) take notice of the intersection of the Equinoctiall line with the Meridian line, which suppose at S. For these two Equinoctiall intersections and the point *m*, all three together, must do what we now intend.

The thing here now intended is, to know what angle is contained between the two superficies X A B, and X A T, which are two Meridian circles, or (which is the same) the angle V *m* S in the plain of the Equinoctiall, which angle measures the said inclination of the two forenamed Meridians, as it doth of all Meridians.

Now to measure this angle V *m* S, the best way will be first to extend two threeds, one from V to *m*, and the other from S to *m*, crossing each other at *m*, and they may be continued further till they meet with some object (in the way standing, or else set for that purpose) where they may be both fixed as at F and G. Then measure from S to *m*, and from V to *m*, which is the shortest, suppose S *m* to be the shortest, and V *m* the longest. First, take V *m*, and lay it down in a line, as there is done. Then take S *m*, and measure it on the same line from M to S or D. Thirdly, take the distance from V to D out of this line, and set it from V to D, upon the line V *m*, so shall *m* S and *m* D be equall one to the other. To this distance therefore *m* S or *m* D as a Radius, open some line of Chords, then take the Chord or subtense from S to D (S is a stable point upon which you may firmly set your Compasses) and measure the same length upon your line of Chords, where you shall see how many degrees the angle S *m* D or S *m* V containeth.

Now all this busines is to finde how great an angle is contained between the South part of the Meridian of the

place

place, and the Meridian belonging properly to the Zenith line. But here (if it be obſerved well) the angle now meaſured is made between the proper Meridian and the North part of the Meridian of the place, ſo that this angle muſt be the ſupplement (to a Semicircle) of what is required. The ſupplement therefore of the angle now found, is (in this caſe) the Longitude or Meridian into which the Zenith line A B pointeth. I ſay the ſupplement of that angle is the proper Meridian of the Zenith line; or the difference of Longitude proper to that line, from the Meridian of the place. But foraſmuch as the angle V *m* S doth meaſure the inclination or angle of this proper Meridian from the North part of the Meridian of the place, and that the ſhadow of the Index A B doth firſt come to the proper Meridian A O before it comes to A T the Meridian of the place: we may therefore in ſuch caſe ſay, that the angle V *m* S gives the difference of Longitude; and that the ſaid difference of Longitude lies Eaſtward from the South part of the Meridian of the place, as there in the Figure it appears to lie Weſtward from the North part. Suppoſe that the difference of Longitude were 39 *gr.* 25 *min.* and the proper Latitude 40 *gr.* And ſo much for this alſo.

If this way be thought not feaſible enough, the former in the ſecond Propoſition may be uſed; yet variety in all kindes is delightfull, and not to be rejected in this. It is done, you ſee, without having reſpect to any declination or re-in-clination, which the former was founded upon.

5. *How to forme the Angles at the Pole.*

THis Propoſition makes way for computing Tables of Horizontall ſpaces, and Equinoctiall Altitudes to any Longitude or Meridian differing from the Longitude of the

Eaſt hour.	*generall Table*		*Weſt hours*
12	0	00	12
	3	45 ——	*a*
	7	30 ——	*b*
	11	15 ——	*c*
11	15	00	1-*d*
	18	45	
	22	30	
	26	15	
10	30	00	2
	33	45	
	37	30	
A-	1	55	
	39	25	
	1	50	
	41	15	
9	45	00	3
	48	45	
	52	30	
	56	15	
8	60	00	4
	63	45	
	67	30	
	71	15	
7	75	00	5
	78	45	
	82	30	
	86	15	

eaſt hou	*generall Table*		*weſt hour*
6	90	00	6
	93	45	
	97	30	
	101	15	
5	105	00	7
	108	45	
	112	30	
	116	15	
4	120	00	8
	123	45	
	127	30	
	131	15	
3	135	00	9
	138	45	
	142	30	
	146	15	
2	150	00	10
	153	45	
	157	30	
	161	15	
1	165	00	11
	168	45	
	172	30	
	176	15	
12	180	00	12

Angles at the Pole.		
s	88	10 *n*
3 *t*	84	25 *n*
v	80	40 *n*
	76	55 *n*
	73	10 *n*
2	69	25 *n*
	65	40 *n*
	61	55 *m*
	58	10 *m*
1	54	25 *m*
	50	40 *m*
	46	55 *m*
	43	10 *m*
12	39	25 *m*
	35	40 *m*
	31	55 *m*
	28	10 *l*
11	24	25 *k*
	20	40 *i*
	16	55 *h*
	13	10 *g*
10 *y*	09	25 *f*
x	05	40 *e*
w	01	55 *r*

Angles at the Pole.		
Proper Merid.	00	00-
p	01	50 *r*
qq	05	35 *e*
r	09	20 *f*
	13	05 *g*
	16	50 *h*
8	20	35 *i*
	24	20 *k*
	28	05 *l*
	31	50 *m*
7	35	35 *m*
	39	20 *m*
	43	05 *m*
	46	50 *m*
6	50	35 *m*
	54	20 *m*
	58	05 *m*
	61	50 *n*
5	65	35 *n*
	69	20 *n*
	73	05 *n*
	76	50 *n*
4*ſt*	80	35 *n*
u	84	20 *n*
z	88	05 *n*

place,

place, and to any Latitude differing from the Latitude of your place. After that the difference of Longitude is known, you are first to frame a Table of angles at the Pole, which will not be hard to perform, and the manner of it will be seen best in an Example, being altogether like the computation of the said angles at the Pole for the houres of any place to the same declining plain.

I have here first of all in a generall Table set down the graduall distances of houres and quarters from 12 at noon or mid-day, which will be some help in performing the work. The houres that are on the left side of the degrees are the East or forenoon houres, and those on the right hand are the West or afternoon houres. Suppose (as before *Prop.* 4.) a difference of Longitude were given *39 gr. 25 min.* towards the East, and it were required to know what angles our hours (namely those 12 that stand neerest to it, six upon one side, and six upon the other) with their intermediate quarters do make with this Longitude or Proper Meridian, for so I intend to call it.

I first take the given Longitude or Proper Meridian, *39 gr. 25 min* and enter it among the East houres of the generall Table, and I finde it to fall in at A; that is, between a quarter and halfe an houre past 9 before noon, and I finde also the circumstant numbers to be 37. 30 the lesser, and 41. 15 the greater. The differences between these two numbers and the Longitude given, are *1 gr. 55 min.* and *1 gr. 50 min.* as you see them set down in the said generall Table right against the letter A.

These two differences are to be first placed in this second Table of Angles at the Pole, as you see in the Example, where, first of all is written Proper Meridian 00. 00 separated from the rest as signifying only the place where it is to stand,

ſtand, and above it is placed (the difference between 37. 30 and the proper Meridian 39. 25, namely) 1 *gr.* 55 *min.* So again, below it is placed 1 *gr.* 50 *min.* (which is the difference of 39 *gr.* 25 *min.* the proper Meridian from the next greater number 41 *gr.* 15 *min.*) Now to theſe two radicall numbers, I adde $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{4}$ and one whole houre, namely *a*, *b*, *c*, and thereby produce *e*, *f*, *g*, on both ſides the proper Meridian. Then to *r*, *e*, *f*, *g*, I adde 15 *gr.* *d*, namely, the number of one houre, and thereby do further produce *h*, *i*, *k*, *l*, on both ſides the Proper Meridian, as before. And afterwards for more eaſe, to the numbers *r*, *e*, *f*, *g*, *h*, *i*, *k*, *l*, I adde 30 *gr.* or two houres, and do thereby produce on both ſides the eight numbers noted with the letter *m*. And ſo ſtill adding 30 *gr.* to the laſt eight numbers noted with *m*, or elſe adding 60 *gr.* to the firſt eight numbers noted with *r*, *e*, *f*, *g*, *h*, *i*, *k*, *l*, I ſhall make the eight remaining numbers noted with the letter *n*, both above and below, on both ſides the Proper Meridian. And ſo this Table of Angles at the Pole is compleated, for if it ſhould (in the ſame manner) be further continued, the next numbers (above) would be 91 *gr.* 55 *min.* and (below) 91 *gr.* 50 *min.* both greater than 90 *gr.* beyond which there will be neither need nor expedience to go.

This way of forming the angles I thought beſt to take, becauſe it is more plain and eaſie than any other, which elſe might have been in this work uſed.

You are afterward to place the houres (in this laſt Table) about the Proper Meridian, juſt as you ſee their order to be about the letter A in the general Table, and as you ſee they are in this particular Table of Angles at the Pole.

The like work ſerves for Weſt Longitudes.

Thus you have the angles for 12 houres and their quarters, the

the same angles serve for the other 12 houres: and whatsoever is hereafter computed for any of these 12 houres, must be understood to serve also for the 12 opposites, and so the work will be done for the whole Circle, or 24 houres of the naturall day.

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6. *By knowing the angles at the Pole, and the Latitude of the place or Horizon, how to finde the Horizontall Spaces thereto belonging.*

WE must suppose that this Longitude or Meridian which we have before mentioned, is proper to some Horizon or other, above which also the elevation of the Pole must be imagined known, which we may suppose to be 40 *gr.* as before, *Prop.* 4. In respect of this plain or Horizon it is, that the Spaces now mentioned are called Horizontall Spaces.

The way to finde them for this Ellipticall work is converse to that which is usuall in declining plains. Namely thus,

As the Sine of the Poles elevation above this Horizon or
Is to the Radius; [Plain,
So is the Tangent of each of these angles at the Pole,
To the Tangent of the Horizontall space belonging to each of those foresaid angles.

So having found all these Horizontall spaces severally by this form of calculation, you may set them into a Table, as here you see it done in the first of the two main Columns. They signifie the distances of every of the houres and quarters

quarters from the proper Meridian, and are to be accounted as numbered in the degrees of the ſaid plain or Horizon.

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7. *By knowing the angles at the Pole, and the Latitude of the plain or Horizon, how to finde the Equinoctiall Altitudes or depreſſions (above or under the ſame Horizon) due to the ſaid Angles at the Pole or points of the Equinoctiall.*

THe proportion by which this is to be effected is this.

As the Radius,
Is to the Co-ſine of the Poles elevation above the plain or Horizon;
So is the Co-ſine of any of the Angles ſpecified in the former Table of Angles at the Pole;
To the Sine of the Altitude required, and due to that angle, or houre (rather) in the Equinoctiall Circle.

So in the former example. The Latitude or elevation of the Pole above the Horizon was 40 *gr.* the complement of that is 50 *gr.* which is the Meridian altitude and depreſſion of the Equinoctiall Circle above and under the ſaid Horizon or plain, and is therefore to be ſet for the altitude of the proper Meridian. Now,

As the Radius,
Is to the altitude of 50 *gr.*
So is the Co-ſine of every angle at the Pole, or arke of the Equinoctiall in the former Table,
To the Altitude due thereunto.

And

hours	Horizon Spaces		altitudes or profu.		hours
	88	49	1	24	
3	86	24	4	16	3
	83	58	7	08	
	81	30	9	59	
	79	00	12	49	
2	76	26	15	37	2
	73	48	18	24	
	71	04	21	08	
	68	15	23	50	
1	65	18	26	28	1
	62	13	29	03	
	59	00	31	33	
	55	35	33	58	
12	51	58	36	17	12
	48	09	38	29	
	44	06	40	33	
	39	48	42	29	
11	35	14	44	14	11
	30	24	45	47	
	25	19	47	8	
	20	00	48	14	
10	14	28	49	05	10
	8	47	49	40	
	2	59	49	58	

hours	Horizon Spaces.		altitudes or profun		hours
Proper Merid.	00	00	50	00	
	2	51	49	58	
9	8	39	49	40	9
	14	21	49	06	
	19	53	48	16	
	25	13	47	09	
8	30	18	45	49	8
	35	08	44	16	
	39	42	42	31	
	44	00	40	36	
7	48	04	38	32	7
	51	53	36	20	
	55	30	34	01	
	58	55	31	36	
6	62	09	29	06	6
	65	14	26	32	
	68	11	23	53	
	71	00	21	12	
5	73	44	18	28	5
	76	22	15	41	
	78	56	12	53	
	81	27	10	03	
4	83	55	7	12	4
	86	21	4	20	
	88	46	1	28	

And note that *r e f g h, &c.* below the propet Meridian in the Table of Angles, are complements to *n n n n n, &c.* at the top of the Table of Angles: and again, those *r e f g h, &c.* above the proper Meridian, are complements to the lowest *n n n n n, &c.* successively rising in order one after the other. So that, As the Radius, Is to the Sine of 50 *gr.* So is the Sine of *p q r, &c.* To the Sines of the Altitudes

belonging to *s t v*, *&c.* And ſo again, the Sines of *w x y*, *&c.* to the Sines of the Altitudes belonging to *z u ſt*, *&c.* And accordingly this Table of Altitudes and depreſſions is calculated.

If the Pole be elevated upon the plain or Horizon, above 50 *gr.* it will be ſufficient to compute theſe two Tables to halfe houres only, and ſo to ſave halfe your labour. But in leſſer elevations it is beſt to do it to quarters, as here is done n this Example.

i

8. *How to finde the proper Meridian line duly belonging to any Zenith line caſually placed, and to draw it upon the plain.*

THough the 4. *Propoſition* be not made uſe of for finding the Longitude and Latitude (which of due pertaineth to any Zenith line) but inſtead of it the ſecond precedent be thought moſt fit to be uſed; yet ſo much of the fourth will be beſt to be uſed, as ſhall concern the finding out of the proper Meridian line. That is, you muſt raiſe an Axis from the foot of the Index, as is A X, and then projecting this Axis A X and the Index A B one upon the other, as if they were both one, you ſhall thereby alſo project (by them both together) the *Proper Meridian* belonging to the Zenith line A B, ſuch as (in the figure of the fourth) is A O, which muſt be drawn upon the plain accordingly. The manner, of all the particular workings that do hereunto tend, is ſet down in the fourth precedent Propoſition, and therefore will not here again need to be repeated.

9. *How to draw and divide the Ellipsis into houres and quarters, to an Index casually set, whose Latitude and difference of Longitude is discovered by the former works.*

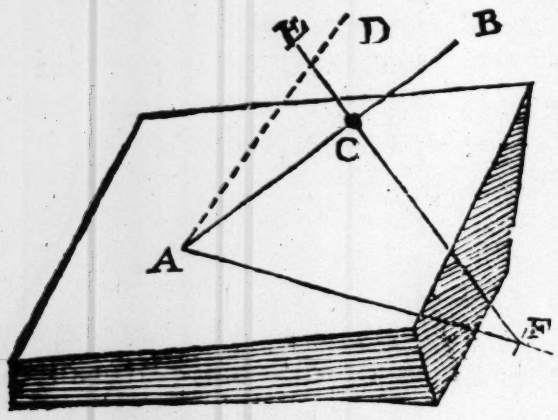
WHen you know the position of your Index in respect of Longitude and Latitude, you may then compute two Tables to the same Meridian or difference of Longitude, and to the Latitude of your Index, as is done before in the 7 *Proposition*, one of which Tables is of Horizontall Spaces, the other of Equinoctiall Altitudes or Depressions above and under that Horizon which is proper to the Index or Zenith line casually placed.

By these two Tables the work will be done in such manner as was shewed before, *Prop.* 2. The manner of the work is this.

1. You are to assume some point in your Index A B, let the point be C, where you may fasten some knot of threed that it may not be lost again.

2. From this point you must draw an Horizontall line, not in the levell of your own Horizon, but in that Horizon which is proper to that Index or Zenith line A B: that is, it must lie perpendicular to A B, making right angles (in every part of it) to that line, and must have respect (in this perpendicularity) to the point C. The meaning is, you must imagine a plain to passe through the point C, and the same plain to be perpendicular to the line A B; or that the line A B is a perpendicular surgent line to the said plain passing through the point at C.

Now this work will be somewhat hard to perform if A B



be a threed only, and not of ſome more ſturdy ſubſtance. Yet the beſt of it is, that there is no very great preciſeneſſe here required, for the work to be done will be good though this Horizontall plain be not placed ſo exactly perpendicular.

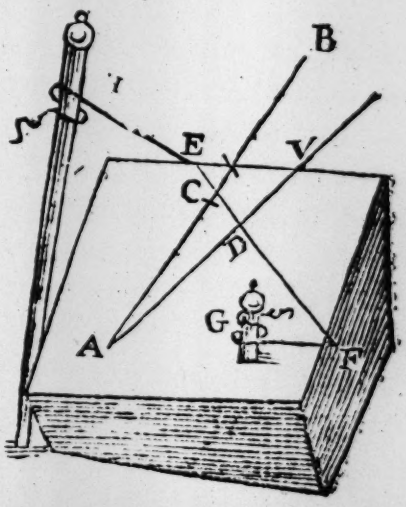
[And ſo it may be noted, that if other Dials be deſcribed by the Equinoctiall Circle and not by the Horizontall, the work of drawing the Equinoctiall perpendicular to the Axis will be difficult, but though no great accurateneſſe be uſed, yet the work will be perfect enough, and no way defective for the loſſe of a degree or two in the perpendicularity required, which I thought good here alſo to note, becauſe I have omitted it in all my other Precepts of Projecting Dials.]

Wherefore you may do it by ſome Paſtboard, applying one edge of it to any line projected from A B the Index, as to A D, and keeping the edge there, you may turn the flat of it to the Index A B, and draw a line by it, or make two pricks through it into the paſtboard, whereby a line may be drawn, but above all note the point C upon it. Then to this line of the Index thus drawn, and from the noted point of it at C, erect a perpendicular: So applying your Paſtboard

to

to its former place again (the edge of it lying upon A D, and the flat of it applyed to the Index A B, and the point in it, noted for C, being again fitted to C in the Index, I ſay thus doing) you may note where the laſt drawn perpendicular doth cut the line A D (which muſt be extended by help of ſome threed if need be) ſuppoſe at E: at the point E (then) you muſt ſay that one point of the proper Horizontall line is to be taken. Then in like manner you muſt ſeeke another Horizontall point: firſt by projecting a line from the Index (any where) ſuch as is A F, and by applying one edge of a paſtboard to that line, and the plain of that paſtboard to the Index A B, and ſo noting the point C, and drawing or marking the line A B upon it, &c. as was done before. So you ſhall finde another point of the ſame Horizontal line or plain (rather) which ſuppoſe to fall at F.

Now having three points of the Horizontall plain at C, E, and F, (which I ſuppoſe not to lie in one and the ſame right line, for that muſt with carefulneſſe be avoided here) you may project ſome part of that line upon the plain, as E F, the reſt of it (ſo much as ſhall be found uſefull) may be made up with returns of threed, and regulated or kept in the ſame plain by projection, as the manner of working that way uſeth to be, and as here you ſee expreſt, by the line H E F G, lying in the ſame plain with the point C, and that whole plain lying perpendicular to the Index A B.



3. The next thing to be done is the drawing of the houre lines upon the plain. And the firſt thing

thing here presuppoſed to be done, is the drawing of the proper Meridian, performed by the 8 *Prop.* That (I ſay) is ſuppoſed as already done before any of this work is begun. Let the proper Meridian be A V. Having then made Tables (by the 7 *Prop.*) for the Horizontall Spaces of your hours from this proper Meridian A B; you muſt firſt apply a paſtboard to the Horizontall line E F, and fit the center of it to C: and upon the Paſtboard, project the proper Meridian from C to A V, or from C to P. And then by the Table of Horizontall Spaces in the 7 *Prop.* (for we now here ſuppoſe that this is the Diall for which thoſe Tables were computed) you may (upon that paſtboard) ſet off all the houres and quarters from the proper Meridian upon this paſtboard: and applying the paſtboard into its proper place, namely to the Horizontall line E P F, and to the point C, you may project the houres and parts of houres from the Paſtboard to the horizontall line H E P F G, as the manner in this way of Dialling is well known.

4. Having transferred the houre-points into the Horizontall line, you may (by help of your Index A B) project and draw the houre lines upon the plain, which we will ſuppoſe done, becauſe the manner of doing it is the ſame with that which was done before for upright Indexes.

5. To know where the Ellipticall line muſt come, or to finde the points in thoſe houre lines, through which it muſt paſſe, we muſt work in the ſame manner as before (in the 7 §. of *Pag.* 73.) is expreſt, namely thus. We muſt make a Scale of right Sines of a fit length, and number them Verſedly, and out of that Scale we muſt take ſuch Altitudes or Profundities (which you will, one or both) as the Table *Pag* 97. giveth, which Table we here ſuppoſe to be computed for this Example whereabout we now are. And taking

theſe

theſe Altitudes from that Scale (that is, from the end at 90, to the altitude numbered upon the parts of the Scale) we muſt inſert them into their reſpective houres to which they belong. They muſt be inſerted in this manner. Having taken any altitude out of the Scale, and found the houre upon which it muſt be placed, you muſt ſet one foot of that extent upon the houre line (keeping it alwayes thereon, but) removing it untill the other foot being turned about, may only touch the fiduciall edge of the Index: and when the feet of the Compaſſes are thus fitted, you muſt note upon what point of the houre-line the foot that is thereon doth ſtand, for through that point of that houre muſt the Ellipticall line paſſe.

The ſame manner of work you muſt perform upon every houre, untill you have gone through 12 of them, which do make up halfe the houres of the whole Diall. And if you ſtrike the lines through the center, you ſhall have all the 24. And looke what is done upon any one houre line, the ſame is to be done upon the oppoſite. That is, looke what diſtance (upon a plain) the Ellipſis hath from the center upon any one line, the ſelfe ſame diſtance from the center muſt the oppoſite line have. But if the deſcription be made upon an uneven ſuperficies, then this rule may not, perhaps, hold: yet this will; namely, Looke what diſtance from the Index (the leaſt or perpendicular Index I mean) any point of the Ellipſis hath, the ſame perpendicular diſtance is to be given for the Ellipſis upon the oppoſite houre line. And by this means you may put in as many houres and Ellipticall points as you pleaſe. And through theſe points you are to draw the Elliptical line.

10. *Concern-*

10. *Concerning the motion that is to be made, either by the Index, or by the Ellipsis it selfe.*

THe motion must be either in, or else parallel to, the proper Meridian, and not elsewhere. Now if the Diall Superficies be made to slide, and the Index stand still; then (though the Diall be upon an unequall superficies, yet) the motion or sliding must be upon a plain. And it must be upon the proper Meridian, projected by the Index from the Diall plate, unto or upon that said plain, and the motion must be in or parallel to it. And it must be noted, that this proper Meridian thus projected never falls directly under any Index that is (not direct but) declining, but it falls aside from it, according as the Index stands aside from the proper Meridian upon the Diall superficies, and as it shall be laid by projecting it.

But if the Index move (the Diall standing still) then the fiduciall edge of it must be made to move alwayes according to, and in the very proper Meridian line it selfe, and not any where else, which may be contrived sundry wayes, as every man shall invent to his own liking. Great care must be had that the fiduciall edge of the Index (in the motion of it) keepe alwayes one justly parallel situation.

11. *Of the place of the Suns Annuall course or Zodiac.*

THe best place for it is to be considered of according to that which moveth.

If the Diall Superficies move, it must (though it be rough (as I said before) yet it must) move upon a plain, this plain there-

therefore in this caſe is fitteſt to receive rhe Zodiac. And then there may a peculiar point or threed Index(ſerving only for the Zodiac) be ſet upon the Diall-moving-plate, whereby it may be rectified according to the time of the year.

If the Index be made to move, then either the Zodiac may be ſet upon the foot of the Index which guides the motion of it, and the peculiar or Zodiacall Index may be ſet ſomewhere where it may ſtand to point at the Zodiac. Or elſe the Zodiac it ſelfe may have its place upon ſome part of the ſtanding plate or body, and the Zodiacall Index may be placed upon the foot of the Diall Index; from whence it may be made to ſhew the Zodiacall parts, as occaſion ſhall be.

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12. *How the Zodiac is to be limited in regard of length, and how to be deſcribed and ſet in its true place.*

THe limitation of it muſt be according to the Scale of Sines by which the Ellipſis is deſcribed, which Scale is mentioned *Pag* 102 §. 5. and *Pag.* 73 §. 7.

The Index or Diall plate (that is the mover) muſt move according to the proper Meridian of the Diall Superficies, and preciſely ſo, as that fiducial edge of the Index muſt move (not elſwhere, but) in the very proper Meridian it ſelf. This is, if the Index move. But if the Diall Superficies move, then the proper Meridian thereof (or the Superficies of the proper Meridian, namely the Superficies made by the proper Meridian cutting through the Diall plate, which is of any thickneſſe) muſt move directly upon, or through, the fiduciall edge of the Index. Theſe things are intimated before. And that the Zodiac is to be deſcribed upon a plain,

though the Diall it ſelfe be not ſo. And further, that if the Diall plate move, (though it be not a plain it ſelfe, yet) it muſt move upon a plain, and that the proper Meridian is to be deſcribed upon the ſame plain, and the motion to be directed according thereunto. Theſe things are often inculcated, becauſe they are hard to be conceived, and had need of the better conſideration for that reaſon. Now further.

1. If the Diall plate be ſuppoſed thus to move upon a plain, and on it the proper Meridian be drawn, then firſt of all, The angle is to be inquired that is made between the Index and that part of the proper Meridian which is projected upon the plain whereon the motion is made, which how to meaſure will be a hard matter to give rules for, becauſe the variety of caſes and poſitions of one to the other will be ſo various. It is firſt to be ſuppoſed, that it makes a juſt right angle with it, and conſequently that the Zodiac is deſcribed upon the proper horizon of the Index. And if upon this ſuppoſition the Zodiac be to be limited, then the rule will be the ſame with the former given in the like caſe, namely thus. Upon your Scale of Sines (by which you deſcribed your Ellipticall line) take from 90, to the Latitude of the Index, and count that length for a new Radius, and keepe it. Then when you have found the forenamed angle (of finding which more is ſaid *Prop.* 13. following) to this new Radius finde the Secant of the complement or exceſſe of that angle: this length or Secant will be the Tangent of 45 *gr.* or the Decimall Scale by which you are to deſcribe the Zodiac on both ſides from the Equinoctiall point or line, according to the numbers in the generall Tables made for this purpoſe, *Pag.* 4, 5, 6, and 7.

[For placing the Equinoctiall point in the Zodiac (upon which all the other parts of that Scale do depend)

you muſt ſet all in the ſame poſture that they had when the Diall was deſcribed: and when you have made fit place for the Zodiac, and ſet on ſome peculiar Zodiacall Index, you muſt note the place upon which the ſaid Zodiacall Index pointeth, for that place is the peculiar place for the Equinoctiall, from whence all the other parts of the Suns annuall courſe muſt be ſet on.]

2. If the Index be made to move in any depth under the Diall ſuperficies, then a ſlit muſt be made in the ſame Superficies that the proper Meridian would cut, and the Index continued therein, down into one ſtreight line till it meet with the foot whereon the Index is fixed, and which being moved, carryeth the Index along with it. And the Zodiac muſt be deſcribed either upon this foot (the Zodiacall Index being made to ſtand ſtill while that ſaid foot with its diviſions moveth) and that alſo parallel to (or in) the proper Meridian projected upon it: or elſe the foot muſt carry the Zodiacall Index, and the Zodiac muſt be deſcribed upon ſome other convenient place, as the ſides (&c.) of that foremention ed flat. And here, for limitation of the Zodiacs length, you muſt finde the Inclination of this moving foot to the Index or Zenith line (which angle of inclination is mentioned before, and ſpoken of afterwards in the 13 *Prop.* following) and work directly as you did before by finding the new Radius, and the Secant of the complement (or exceſſe) of the angle. By which you ſhall finde the Tangent of 45 *gr.* or the length of your Decimall Scale, out of which the Zodiac may be deſcribed by the Tables *Pag.* 4, 5, &c. as is mentioned before in this propoſition. Thus (in theſe caſes) is the Zodiac to be ſet in its true place, thus it is to be limited and deſcribed.

For Occurrences of other ſorts of Caſes than are here mentioned (whereof there will not be many) he that can underſtand to do theſe things aright, will be able to grapple with them; and for ſuch as do not underſtand what is here ſaid, their beſt courſe is to let theſe difficulties alone.

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13. *How to finde what angle is made between the Index and that part of the proper Meridian which is projected upon the plain whereon the motion is made, or which drawn upon the foot of the Index which maketh the ſame motion.*

THe way that for the preſent I thinke of is this. Apply a ſtreight edge of paſtboard to the projected line, and the plain of the ſame paſtboard to the fiduciall edge of the Index, and make two points upon the paſtboard, by or through which the ſame fiduciall edge paſſeth. Then taking away the Paſtboard, draw a ſtreight line through thoſe two points or marks, and ſo meaſure the angle made between the forenamed edge of the paſtboard and this right line. If it be ſo that the line croſſeth not the edge of the Paſtboard, then draw ſuch a parallel line to the edge as may croſſe the former line, and then with a Scale of Chords you may meaſure the angle.

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14. *Further obſervations concerning the motion and daily fitting of the Diall and Index, for ſetting them true.*

1. THe beſt way is to make the Diall plate move, and the Index to ſtand ſtill (in theſe obliquely ſituated Index-

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es) for the Zodiac will (in ſuch caſes) be moſt eaſily deſcribed and made uſefull. And in this caſe the Index may be alſo ſet faſt firſt, and quite finiſhed before the Diall be drawn at all. Then alſo the Diall will be drawn more eaſily, and the motion of the Diall plate may ſooner (this way) be contrived, then can the motion of the Index be contrived when the ſaid Index is to move and the Diall ſtand ſtill. The motion (as hath been often ſaid) muſt be according (that is parallel) to the proper Meridian: and the ſlit (for the fiduciall edge of the Index) may be ſo contrived that the fiduciall edge it ſelfe (which is beſt to be a fine threed) may be alſo the proper Index, and the Zodiac may be deſcribed upon the Diall-moving-plate, cloſely contrived to the threed. Or thus at leaſt, The length of the whole Zodiac may be ſo limited as is before mentioned, and then if you deſire to have it drawn upon ſome other place of the plain upon which the Diall ſuperficies moveth, and the ſame Diall plate to carry the peculiar Index for the Zodiac; then (I ſay) by theſe two terms prefixed to the length of the Zodiac (by the fiduciall edge of the Index) having reference to the Diall-moving-plate (as before) you may determine the length of the ſame Zodiac upon the ſtanding plate whereon the Diall plate moveth, for the new Zodiacall Index ſet faſt into the moving plate, will (upon the ſtanding plate) ſhew the terms of the ſame Zodiac ſuting with the terms upon the moving plate fitted to the ſtanding Index. This will be direction enough becauſe one way may ſerve as well as many. Yet I doubt not to ſet down many more which would be without end, if they were all put together, for inventions in this kinde would be too too many.

2. If the Index be thought beſt to move, then muſt a pattern of it (that is ſome threed) be firſt ſet up. And to this

vice-Index

vice-Index muſt the Diall be deſcribed upon the plain (or whatever curved Superficies it be.) And the Zodiac is beſt to be fitted either upon the plain whereon the foot of the Index is to move (for a plain it muſt move upon, whatever be the Superficies whereon the Diall is deſcribed) and that ſame foot to carry the Zodiacall Index upon it; or elſe upon the foot of the Index, and the Zodiacall or peculiar Index to ſtand fixt upon the plain (or Diall ſuperficies.) And then when all this is done, the vice-Index muſt be taken away and a true ſubſtantiall Index put in the place of it. And for that purpoſe, you were beſt, before you take it away, to finde at what elevation it ſtood from the plain, and likewiſe to draw the perpendicular juſt under it. For by theſe two helps you may ſet up a true ſubſtantiall Index, regulating it thereby into the ſame poſition; which to do, muſt be left to the judgement of every man to contrive as he ſhall ſee requiſite.

But in both theſe wayes care muſt be had what inclination the Zodiacall Scale hath to the Index, according to what is ſaid in the 13 *Prop.*

3. It muſt here again be taken for a Rule, that a plain, if it lie parallel to the index is not poſſibly capable of theſe kindes of Ellipticall houres, but the Index muſt have ſome inclination to the plain, and make ſome angle with the ſame.

4. All theſe Precepts do ſerve to make ſuch Dials as are upon fixed walls or Superficies that cannot be removed. But if it be to be done for moveable Bodies, if they be regularly cut, then the declinations of every of the plains are known by their regularity; ſo that ſuch plains of them as are capable of any Diall before mentioned (for the Index and the plain muſt not be parallel in any caſe, they may be perpendicular) may have ſuch Dials upon them as they are capable of, either to Indexes perpendicular to their plains, or to Indexes lying

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in the Zenith line of the place. But for theſe caſuall Indexes upon them, you will be put to it, to know what declinations they have from the Meridian upon the regular body (for I ſuppoſe that there is a Meridian drawn upon ſome one of the plains or other.) The way that for the preſent I think upon is this. Set the Body upon the foot true in reſpect of horizontall or upright poſition, that is, let the foot of it ſtand upon ſome juſt horizontall plain, though in reſpect of declination it ſtand at all adventures. Then from the fiduciall edge of your caſuall Index, let fall a perpendicular (I mean perpendicular to the Horizon of the place, not to the plain) and to that perpendicular point, from the point of the Indexes concourſe with the plain, draw a right line; this line ſhall repreſent the Azimuth wherein the ſaid Index lyeth. Then again, with your eye repoſe a perpendicular hanging threed upon the two points (namely, the center or concourſe of the Index with the plain, and the late found perpendicular point) both together, and project the umbrage of the threed ſo hanging upon the Horizontall plain. So alſo you muſt repoſe the ſhadow of ſome one of the Cocks or Axes with your eye, upon the Meridian or line of 12, and then alſo the perpendicular threed muſt be projected upon them both joyned before into one, ſo that Threed, Stile, and Meridian muſt now be all as one line; and the threed ſo hanging project the ſhadow of it upon the ſame Horizontall plain. Now theſe two lines thus projected either do concur and make an angle, or elſe (by drawing a parallel to one of them through the other) they muſt be made to concur, and looke what angle they make at their concurrence, the ſame being counted the right way is the angle of the caſuall Indexes declination from the Meridian line. Thus the Declination is found.

Then

Then the Reclination may be found as before is declared, and by help of them the Longitude and Latitude of the Index may be had, and ſo the Diall made by the precedent Precepts.

A briefe DEMONSTRATION of the 7th. and 8th. Sections.

IN the 7 §. all are made to the *Z*enith line of the place. If therefore you imagine an Horizontall Ellipſis to be deſcribed to that *Z*enith line, and upon that Ellipſis a kinde of compreſſed Cylinder to riſe upright, parallel to the ſaid *Z*enith line, with houre lines raiſed from the ſeverall points of the Horizontall Ellipſis, then will the *Z*enith line ſhew the houre upon thoſe ſurgent lines: and the ſame Index (or *Z*enith line) muſt ſhew the houre among thoſe upright lines in the compreſſed Cylinder, by the ſame reaſon that it doth upon the Ellipſis it ſelfe, upon which the ſaid Cylinder is raiſed, And if ſo, then it matters not what part of theſe lines is taken in for this uſe, ſince any one point of them will ſerve to do the work. The way therefore that is uſed for the projecting of theſe houres (by help of the Table in 29 *Pag.*) as it will ſerve to finde the Ellipticall peints upon the Horizontall plain it ſelfe, ſo muſt it ſerve to finde ſome one

one point of theſe ſurgent houre lines upon any other Superficies, becauſe they keepe the ſame diſtances alwayes from the Zenith line (from whence the projection of them is made, and whereon they depend altogether) and therefore it findes (upon any Superficies) the points of thoſe lines which paſſe through, or do interſect the Diall Superficies. Therefore it is that theſe Ellipticall points (upon all Superficies) are points of thoſe ſurgent lines riſing from the Horizontall plain, and that the Zenith line muſt have the ſame relation and ſituation to them, that it had to the points upon the Horizontall plain it ſelfe, And conſequently, that this way muſt be of the ſame truth upon any Superficies that it is upon the Horizontall. So much for any upright Index, ſet upon all ſorts of Superficies, with the houres thereon depending.

In the 8 §. are handled caſuall Indexes; which if well conſidered will fall to be the ſame with them in the 7 §. For the Table of Angles and Altitudes by which they are made, are calculated to that Horizon which is proper to the Index, conſidered as a Zenith line. And ſo from that Horizon we may imagine the like ſurgent lines to riſe all parallel to the Index or Zenith line, and the very ſame reaſon to hold in theſe, that held in the former.

To the Reader that ſhall have the view of this firſt draught of Precepts.

THeſe Rules here given may ſeeme to be ſtuffed with many impertinencies, and ſome needleſſe difficulties, which the Author acknowledgeth willingly, and excuſeth, by reaſon that they were his firſt meditations in this kinde; and ſo much the more undigeſted by how much the leſſe practiſe hath been by him uſed therein. The truth is, he never deſcribed any thing ſuitable to the Caſes of theſe two laſt Sections. And if the Reader be any way able to diſcern what it is to write upon a Mathematicall Subject wherein hath preceded no reall repreſentation, he will not only excuſe difficulties and impertinencies in the tradition, but will wonder if there be not ſome miſcarriages in point of truth: of which (notwithſtanding) the Author is confident this Treatiſe is clear. *S. Foſter.*

15. *Having placed a Diall plate to move (let the Coaſt of the motion be caſuall) how to fit a ſtedfaſt Index to it, and to deſcribe an Ellipticall Diall upon the ſaid moving plain.*

THis Caſe was forgotten before, but now here ſupplyed. You muſt obſerve the line (upon the immoveable plate) which the midſt of the moving plate doth deſcribe, and ſuppoſe that line to be the proper Meridian. Then from ſome convenient point of that proper Meridian, raiſe a true Axis. Project the Axis upon the proper Meridian, and from any point of the ſaid Meridian raiſe a threed (or Index) any where, only ſo as that both this Threed, the Axis, and the Proper Meridian may all three appear in one line. There fix the threed, and then finde the Longitude and Latitude of it, and afterwards deſcribe the Diall to it, according to the rules given before.

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16. *If an Index ſhould be ſet up and made moveable upon a ſtanding plain, there can no Diall be deſcribed thereto,*

UNleſſe the Index be made of wire or ſome ſuch bending ſubſtance, but to ſuch there may. For if you obſerve what ſtreight line the foot makes in its motion, you muſt count that as the proper Meridian, and ſo ſetting up an Axis to ſome point of it, you may put in an Index into that foot, ſo as the Axis, and fiduciall edge of the Index, and the Proper Meridian, may all three appear in one line. And then finiſh your work as is before directed.

FINIS.

CIRCULAR Horologiography.

SHEWING,
How to make an Horizontall Diall in a Circle equally divided, to ſhew the Hour of the day, and Azimuth of the Sun.

Invented and written by
Mr. *SAMUEL FOSTER,*
Late profeſſor of Aſtronomie in *Greſham*-Colledge.

London, Printed for *Nicholas Bourn*. 1654.

CIRCULAR Horologiography.

How to make an Horizontall Diall in a Circle equally divided, to ſhew the Houre of the day, and Azimuth of the Sun.

HEre before we have had *ELLIPTICAL HOROLOGIOGRAPHY*, now ſhall follow *CIRCULAR HOROLOGIOGRAPHY*, which ſheweth how to make a Diall in a perfect Circle equally divided into houres, (whereby to finde the houre) upon any plain whatſoever.

Divide a Circle into 24 equall parts, and take ſo many of them

them as your Horizon hath houres in the longeſt day, or rather ſo many as the degrees of your greateſt Amplitude (Eaſt and Weſt) from the South do ariſe unto; which here at *London* will be neer 18 of them. Then divide each of theſe parts into 15, which for the Azimuth will ſignifie degrees, for the houre will ſtand for four minutes of time apiece.

The altitude of the Horary Index may thus be found.

Adde your Latitude to 90 *gr.* halfe that ſumme is the elevation of the Horary Index above the Horizon. Thus at *London*, $\frac{51\frac{1}{2}+90}{2}=70\ gr.\ 45\ min.$ which is the altitude or elevation required. Or, adde halfe the complement of your Latitude (which is $19\frac{1}{4}$) to your Latitude ($51\frac{1}{2}$) the ſum ($70\frac{3}{4}$) is the elevation of the Index.

The ſtanding and looking of it.

It muſt ſtand right over the line of 12, elevated above the ſaid line $70\frac{1}{4}$ *gr.* and muſt looke toward (but not into) the North Pole.

The motion of the Horary Index.

It muſt move to and fro, directly over the line of 12. Or elſe the houres muſt move to and from it, according to the line of 12, ſo as that the ſame line may alwayes lie under the foot of the ſaid Index. The motion of the one or the other is neceſſary, becauſe elſe the Circle of equall parts can never ſhew the true houre all the year long.

How

How the Zodiac is to be limited, and laid, and charactred.

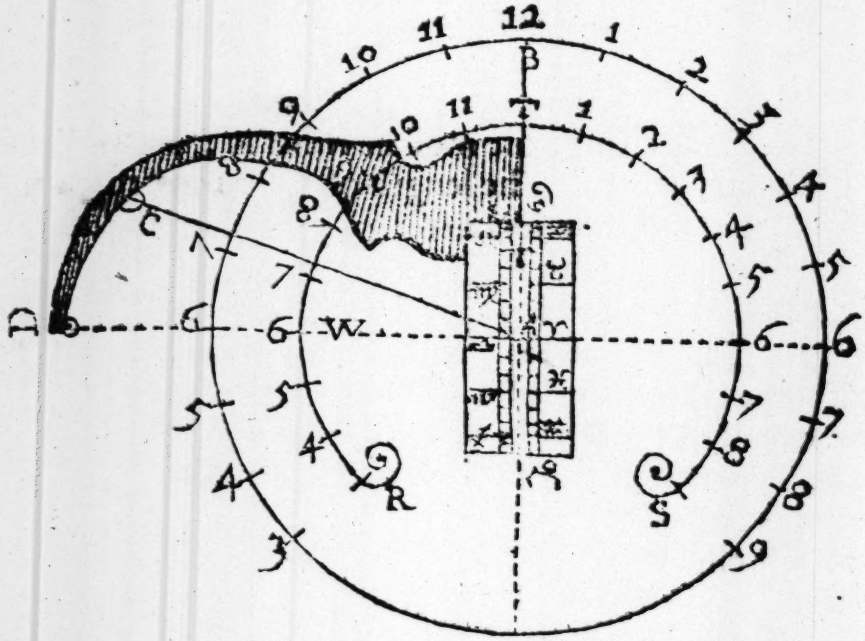
The motion of the Index muſt be regulated by the Zodiac. The Zodiac therefore muſt lie either in, or elſe parallel to the Meridian line. The length of it is thus to be limited. Count the Semidiameter of your Circle (*viz.* A B) for the Radius: to that Radius, Either

1. Make the Sine of $70\frac{1}{4}$ (taken to the Radius of your Circle) a Tangent of $70\frac{1}{4}$; and to the Radius of that Tangent finde the Secant of $19\frac{3}{4}$ (the complement of $70\frac{1}{4}$) that length ſhall be the Radius of the degrees, or the Decimall of the Tangents of the Zodiac, to be inſerted by the Tables *Pag.* 4, 5, 6, and 7.

2. Or elſe, Make the Sine of $19\frac{1}{4}$ (eſtimated to the Semidiameter of the Circle A B as Radius) a Radius, and to that Radius finde the Secant of 19', this laſt length or Secant ſhall be the quantity of the Tangent of 45 *gr.* or of the Decimall Scale by which the numbers *Pag.* 4, 5, &c. are to be inſerted. And in theſe Northern Horizons ♋ and ♑ muſt be placed ſo that 12 may be neereſt to the Index in Summer, and furtheſt off in Winter.

The manner how to faſhion the Cock which holdeth the Index.

The faſhion may be ſeen by the figure A C D. At A is the place of the fiduciall point of the foot of the Index to be aſſigned: and in that point a hole muſt be pierced, and a threed fixed. Then the Cock muſt have two holes more pierced, one at C, the other at D, both to ſtand perpendicularly over the line of 12. That at C muſt be ſo placed, that the angle C A B may be $70\frac{1}{4}$ *gr.* That at D muſt be placed ſo, that D A B may be an angle of 90 *gr.* How



How to place this Diall for use.

YOu must either fix your Diall plate in the Meridian line, and truly Horizontall; or else upon an Horizontall or levell flat you must draw a Meridan line, whereby to place it upon any occasion. Then,

To finde the Houre.

Make use of the Index A C, and rectifie the foot of the Index to the requisite place in the Zodiac, (either to the day of the moneth, or the degree of the Signe.) When it is thus rectified and set, the shadow of the threed A C will shew the houre of the day.

To

To finde the Azimuth.

Put the threed from A to D, and let A D be your Index. Then (alwayes) place the foot of the threed in the center of the Circle at A, So ſhall the threed A D give the Azimuth.

℄ Note, That the Scales of Declination, Amplitude, Aſcenſionall difference, may be placed by the Zodiac, and uſed as is before ſhewed in the Ellipticall Dials.

Another way to make the ſame Horizontall Diall equally divided, to finde the Houre and Azimuth.

THe former way maketh the Index to point up neer to the elevated Pole. This other will require the Index to point towards the contrary Coaſt, namely, that of Noon or Mid day, or toward (but not into) that Coaſt of the heavens where is the depreſſed Pole under the Horizon, but ſtill the Index is to be above the Horizon.

The altitude of the horary Index above the Horizon, muſt be halfe the complement of the Latitude, or halfe the height of the Equinoctiall. Here at *London* $19\frac{1}{2}$ *gr.* which is the complement of the former wayes elevation $70\frac{1}{2}$.

The ſtanding and looking of it, muſt be right over the line of 12, drawn out at competent length, and muſt juſtly point into the Coaſt of 12 mid day: Or towards (but not into) the South (or depreſſed) Pole.

It must move as the former did.

The Zodiac is to be laid as before, and to be limited and characterd thus. The Semidiameter of your Circle being taken for Radius, you must use the two former rules in this manner.

1. Either make the Sine of $19\frac{1}{4}$ a Tangent of $19\frac{1}{4}$, and to the Radius of that Tangent finde the Secant of (the complement of $19\frac{1}{4}$, namely) $70\frac{3}{4}$, that length shall be the Radius of the degrees, or else the Decimall Scale of the Tangents of the Zodiac, and they must be inserted by the Tables *Pag.* 4, 5, &c.

2. Or else, make the Sine of $70\frac{3}{4}$ (estimated to the Semidiameter of the Circle A B as to a Radius) to be a Radius; and to that Radius finde the Secant of $70\frac{1}{4}$, this last length or Secant, shall be the length of the Tangent of 45 *gr.* or of the Decimall Scale, by which the numbers in the Tables *Pag.* 4, 5, &c. are to be inserted.

By this instance for the Horizon of *London*, where the numbers $19\frac{1}{4}$ and $70\frac{3}{4}$ are proper, may the like work be performed in other places of different Latitudes from *London*, only by altering the numbers, according as the proper Latitudes of such places shall require. And in all Northern Horizons ♋ (or the longest dayes) must be so placed that the point of 12 in the Circle may then be neerest to the Index, and in ♑ (or the shortest dayes) it may be furthest of. But in Southern Latitudes, the places of ♋ and ♑ are quite contrary, because there the Sun being in ♑ makes the longest day, and in ♋ the shortest.

The manner of fashioning the Index, of placing the Diall, and using it, is the same as was shewed before.

How

How to make the like Houres and Azimuths by an equally divided Circle, upon all Plains whatsoever.

YOU are first to finde these three things. 1. How much, and which Pole is elevated above your plain, which is equall to the Latitude of your plain. 2. The position of the (usuall substylar or) proper Meridian of the plain. 3. The difference of the Plains Longitude from your own, or the angle at the Pole made between yours and the plains Meridian. And when these things are had, the work will be like that which was before. For the way will be twofold. as there it also was.

The first way.

Take halfe the complement of the plains Latitude, and adde it to the plains Latitude it selfe, the summe will give the elevation of the Index above the plain. This Index is to point towards (but not into) that Pole which is elevated above the plain.

The other circumstantiall things about the Index are as those before, if insteed of the line of 12 there mentioned, we here take the proper Meridian (or Substilar drawn in its right position) of the plain.

The limitation of the Zodiac must be somewhat as before.

That is, you must count the Semidiameter of your Diall Circle to be as the Radius. And to that Radius, 1. Either finde the Sine of the elevation of the Index, and make that Sine a Tangent of the same elevation of the Index; then to the Radius of this Tangent finde the Co-secant of the former elevation, the same Co-secant shall be the Radius or Decimall Scale whereby to insert those dayes or Ellipticall degrees set down in the Tables *Pag.* 4, 5, &c.

2. Or else to that same Radius of the Circle, finde the Co-sine of the elevation of the Index, and to this being made a Radius, finde the Co-secant of the Indexes elevation, and so shall this Co-secant be the Radius or Decimall Scale as before.

The second way.

The altitude of the Index above the plain is the halfe complement of the plains Latitude. The Index must (in this way) point towards (but not into) that Pole which is depressed under the plain (I mean toward that Coast of the world, but must still remain above the plain.)

The standing and motion of the Index, with the characting of the Zodiac, and other circumstantiall matters, as of the Cock for one Index, and the usage for the houre, must be agreeable to the former rules given before.

The limitation of the Zodiac must be done by the two former rules given (in generall terms) in this *Page*.

How to divide the Circle of houres.

It must be divided into 24 equall parts, and those of the 24 taken into use as will be serviceable, the rest left out.

Every

Every of theſe 24 parts may be divided into 15 *gr.* or into quarters and halfe quarters (for here in ſuch plains there will be no Azimuth ſhewed for the place, nor well for the plain it ſelfe, and therefore it is beſt to omit it in theſe altogether.) All the doubt will be where you muſt begin your diviſion.

From the interſection of the proper Meridian (of the plain) with the Circle, ſet off (upon the ſame Circle, and to the true Coaſt) an arke equall to the plains difference of Longitude. And from that point ſo inſerted, (which you muſt ſuppoſe to be the point of 12) you are to begin the diviſion of your Circle. The numbring of the houres on both ſides 12 will not be hard to finde, in reſpect of their courſe, for the courſe of the ſhadow of the Index will give that.

NOTE

1. In all Polar plains (ſuch as our upright Eaſt and Weſt, &c.) the Index in both theſe caſes or wayes (here before given) will be elevated 45 *gr.* and the Radius of the Diall Circle will be the Radius or Decimall Scale by which the Zodiac Scale is to be inſerted out of the Tables, *Pag.* 4, 5, &c.

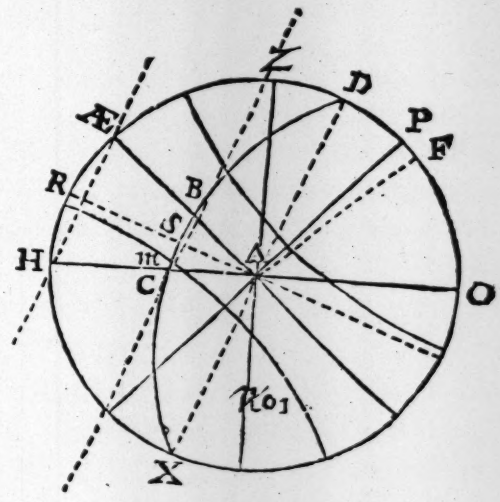
2. If at any time the Zodiac prove longer than the Diameter of the Horologicall Circle, and ſo the Index do go without the Circle; at ſuch time as it is without, the ſhadow of the Index will go one way till it touch the Circle, and then back again the ſame way it formerly came.

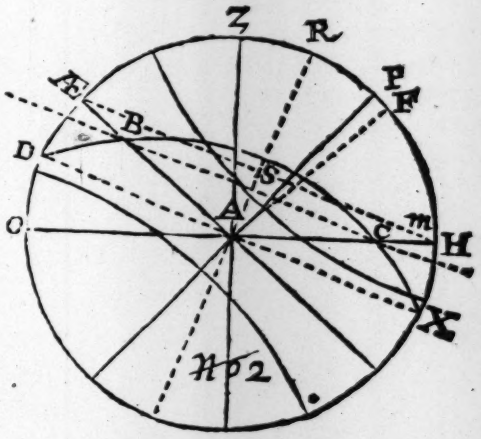
A briefe DEMONSTRATION of theſe Circular wayes of making DIALS.

THe Circular wayes have dependance, and are deduced out of the precedent Ellipticall wayes; and the Caſes are but two, wherein the ſame may be done upon any Horizon or plain, as may be perceived by the former Precepts, wherein the altitudes of the Indexes above the plain are ever made to be either halfe the complement of the Plains Latitude, or elſe (the ſumme of the Latitude and that halfe complement, which ſumme is equall to) the complement of that forenamed halfe complement.

According to theſe two caſes here are two Schemes fitted. The projections are made upon the plain of the Meridian Circle P Z H X. P is the Pole, Z the Zenith of the place, H A the Horizon of the place, Æ A the Equinoctiall Circle, D A and R A are drawn in the middle of Z P and Æ H or Æ O. D B C X repreſents one Azimuth or Verticall Circle proper to the plain R A, and by that one all the reſt of them may be underſtood. D A repreſents the Index in both the former Caſes, and R A the Horizontall plain (not of the place but that Horizontall plain which is) properly

perly belonging to the Index or Zenith line DA. The firſt Scheme ſhews the firſt of the two former Caſes, the ſecond ſhews the ſecond of them. Their Demonſtrations will be both one. For the queſtion in them both is, How to theſe inclinations of the Index, the Diall, or horary line, that falls upon the Horizontall plain of the place, comes to be a perfect Circle.





Firſt, therefore conſider, that in all the Elliptical Dials, the horary line hath relation to the Equinoctiall Circle, and to the Index or line that is to give the ſhadow (whatſoever the Superficies be upon which the projecture is made, whether plain or otherwiſe it matters not, as appears before, but here we deale only with plains, becauſe Ellipſes and Circles are plain Figures.

Secondly, conſider, that through the ſeverall houre points of the Equinoctiall Circle, right lines are to be ſuppoſed to paſſe infinitely extended, till they meet with the plain whereon the projecture is to be deſigned. Which

iſſuing

iſſuing out of theſe infinite lines (if they be regularly cloathed about with an inflected Superficies muſt comprehend a Cylindricall concave, either round or compreſſed according as the forenamed infinite lines are either perpendicular to the plain of the Equinoctiall, or not perpendicular to it.

Thirdly, Theſe parallel lines ſo drawn through the houre points of the Equinoctiall, parallel to the Index, muſt all fall perpendicular to the Horizontall plain which is properly belonging to the Index as a Zenith line. And the ſame lines upon that proper Horizon do alwayes make an Ellipſis, except only theſe two Caſes. Firſt, If the Horizon be the ſame with the Equinoctiall Circle, and the Zenith line or Index the ſame with the Axis of the world, for then thoſe lines do there make a perfect Circle. Secondly, If the Horizon be a Polar or Meridian Horizon, and the Index or Zenith line fall into the Equinoctiall (having no Latitude from it) for then thoſe lines do all fall into (or coincide with) the plain of the Equinoctiall, and conſequently do make (upon their proper Horizon) a direct right line: yea more, becauſe the ſaid lines do lie all upon the plain of the Equinoctiall, and are all drawn out of the equall diviſions of the Equinoctiall Circle, and beſides are all parallel one to the other; therefore they make (in this caſe) a double line of Sines, as is ſaid before in the fifth note *Pag.*37. Now to come to my intended purpoſe, which is, to prove that Indexes ſo laid (as is mentioned before in the two precedent Caſes) will require (upon the Horizontall plain of the place) a true Circle and not an Ellipſis.

Suppoſe therefore D A to be the Index (according to one of the two precedent conditions) then muſt R A be the proper Horizon to that Index. And according to the former Doctrine, if Æ, and B, and A, be taken for three of the houre

houre points in the Equinoctiall, and Azimuths drawn through them from D the Verticall point of the Index, then I say (in these two cases and not otherwise) looke how the Equinoctiall is divided by those Circles, in the same manner is H O the Horizon of the place divided. But because the Equinoctiall is ever equally divided in respect of houres, therefore the Circles from D to X (from the Zenith of the proper Horizon R A to the Nadir, which are Azimuthall Circles) shall cut the Horizon of the place (H O) into equall parts. This, I say, is true, Because D Æ B and X H C are equall Sphericall Triangles in three of their quantities [For D Æ is equall to X H, and the angles at D and X are equall, as also the right angles at Æ and H] and therefore equall in all the rest, if like be compared to like: that is, H C is equall to Æ B; and consequently A C equal to A B: so also C X equall to B D. And if so, then the Chord B C must be parallel to the Index or Zenith line D X, and so Æ H is parallel to D X, and so contrarily (in these two Cases) right lines drawn from the houre points in the Equinoctiall Circle, parallel to the Index, must cut (upon the Horizon of the place) equall parts, equall to one another, and equall to the houres upon the Equinoctiall Circle. That is to say, they cut the horizontall Circle it selfe into 24 equall parts or hours. And consequently (in these two Cases) those forementioned right lines must designe (the horizontall Circle it selfe, that is) a Circle upon the horizontall plain of the place, though upon the proper Horizon it selfe (R A) they must designe an Ellipsis (falling perpendicularly thereon) according to the third observation in the 128 *Pag.* And from that Ellipsis these lines B C, H Æ, may be conceived as surgent lines (such as are mentioned before *Pag.* 113) containing a compressed Cylinder, which Cylinder being cut

two wayes, (that is ſubcontrarily) will again reveile the originall Circle (at leaſt in one of the two Sections) from whence it ſelfe and the ſurgent lines tooke their forme and places.

NOTE.

1. The ſame reaſon holds in all plains, that in them alſo there may be found ſuch a *Circular Horologiography*. For they are Horizons to ſome place of the World or other, and are therefore capable of the ſame accidents that the forementioned Horizon of a particular place is.
2. That theſe Caſes are the ſame (in a manner) with thoſe §. 5. For here a new Zenith line (as D A) is found to H O the Horizon of the place, ſuch a Zenith line (or Index) as may lie equidiſtant from the Horizon of the place HO, and from the Æquinoctiall Circle Æ A: And there there is a plain ſet up which may ſtand ſo, as that the Zenith line of the place may ſtand equally diſtant from the Æquinoctiall Circle and this plain. In both, the Index ſhands equally diſtant from the Equinoctiall, and from the plain whereon the houre points are to be inſerted.

For the limitation of the Zodiac.

The firſt work in the limitation of it is for the Ellipſis that ſhould be deſcribed upon the proper Horizon, and the ground of that is the ſame with what was before delivered *Pag.* 75. The reaſon of both will be plain enough out of the foregoing Diagrams. For the Zenith line D A, if it were to move upon the proper Horizon R A, it muſt move in the proper horizontall Zodiac, as formerly it did, *Pag.* 17, 18. Which Zodiac is to be made as before, and here in the firſt work is ſhewed: the reaſon of the diviſion of it is given in *Pag.* 61, 62. Here is only to be ſhewed the reaſon of the enlarge-

ment.

ment. If the Index were ſet upon the proper Horizon R A, then it muſt move thereon (perpendicularly) from A to S ſuppoſe. But it moves not upon that but upon H O the horizontall plain of the place, and yet to keepe the ſame diſtances in motion from the firſt poſition of it in D A X, that is, it muſt move parallel alwayes to D A, but not upon A S but upon A H, which to do, it muſt not have the parts of the Zodiac in A S (to guide upon H O) but proportionall ones to them, that is, inſtead of A S muſt be taken A *m*; which is all one as to ſay, As A S the Radius, to A *m* the Coſecant of S *m* A, or D A O, the Indexes elevation (above the Horizon H O;) So are the parts of A S the prime or fundamentall Zodiac, to the parts of A *m*, the ſecondary or inlarged Zodiac.

Thus much of Circular Dialling.

APPENDIX.

SEE the Figure in *page* 120. To that Zodiacs length you may finde ſuch a Radius as ſhall be thereto juſtly competent ſo as to make the Ellipticall Horizontall Diall R T S; and having made that Diall, the upright Index D A will give the hour upon it, as the ſlope Iudex A C will give the houre upon the Circle. And theſe two being ſeverall Indexes and Dialls muſt ſet themſelves as the other do, and wil not ſtand right till they agree. Onely this cannot be ſo punctuall, becauſe the two Indexes A C and A D are nor ſo far diſtant as in the other horizontall Diall. But the A-

zimuth will here be ſtill ſhewed, as was mentioned before.

Having the Zodiac limited, how to finde the two extream Diameters of the Ellipſis.

The length of halfe the Zodiac is alwayes to be eſteemed the Tangent of 23½ *gr.* Now becauſe we here ſuppoſe this Zodiac already made, and to be intended for an horizontall Diall; therefore, Either thus,

1 As the Tangent of 23½, is to the Tangent of your Latitude; So the length of the Semizodiac upon your Diall, to the Sine of your latitude, which is the ſhorter Semidiameter A T.

Or elſe thus,

2 As the Tangent of 23½, is to the Radius or Tangent of 45 *gr.* So is your known and limited Zodiac, to the Coſine of your Latitude. The Radius, to which Coſine is the larger Semidiameter A W.

Thus having fitted your Ellipſis (to the Zodiac) you may deſcribe and divide it in ſuch manner, as was formerly ſhewed, *pag.* 1.

FINIS.

RECTILINEAL OR DIAMETRAL Horologiography.

SHEWING

The manner how to deſcribe the Houres upon a finite right line, or the Diameter of a Circle, and to fit a moveable Index unto the Diall ſo deſcribed.

Invented and written by
Mr. *SAMUEL FOSTER*,
Late profeſſor of Aſtronomie in
Greſham-Colledge.

RECTILINEAL OR DIAMETRAL Horologiography.

Concerning Dials made upon a finite ſtreight line, with a moveable Index.

THis may ſeem no difficult nor new thing, ſince the moſt vulgar known way of protracting Dials is either by one contingent line (which is a right line;) or elſe by two Tangent lines, as by the Sector is uſually done. But it muſt be conſidered, that the contingent line is infinite, and this line (here mentioned) is finite. Again, that other way by the Sector, is not by one finite line, but by two at the leaſt; whereas this is by one finite line. Some difference there is. And beſides, that other

by

by Tangents may be as well done upon a ſingle crooked line, this cannot.

This ſtreight line is mentioned before, that in right Horizons or Polar plains the Ellipſis ſhutteth up into a ſtreight line. And it is true, that this falls out to be ſo, onely in right Horizons (if the Index ſtand perpendicular to the plain, as is before intended) which caſes happen but ſeldome, and to ſome plains onely. But here my purpoſe is to ſhew how it may be done to all plains whatſoever: obſerving only this one condition; alwayes to ſet the Index ſo, as to point up into the Equinoctiall Circle: for ſo it muſt do, and will not be done any other way, according to this forme of caſting the houres.

There are two Caſes which will offer themſelves.

The firſt is, when the Index pointeth up both into the Equinoctiall Circle, and likewiſe into the plains proper Meridian Circle.

The ſecond is, when it points up into the Equinoctiall Circle of the heavens (for ſo it muſt ever do) and into ſome other Meridian Circle, ſuch as is not proper to the plain.

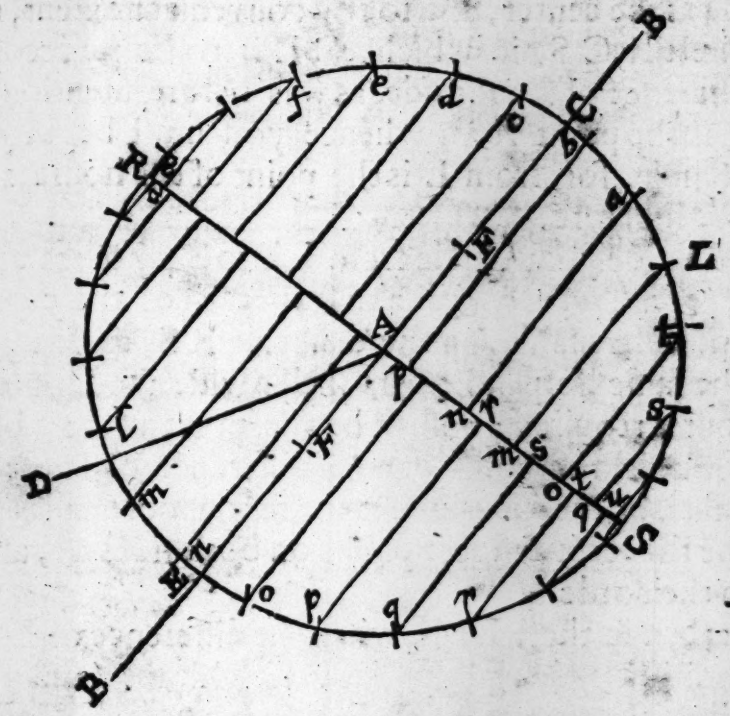
¶ 1. *How to make a Diall upon a finite ſtreight line, drawn upon any plain, the Index being ſo ordered that it point up into the Equinoctiall Circle, and into the plains proper Meridian.*

IN this Caſe, the Index is to lie juſt over the proper Meridian of the plain, and is to be elevated ſo much above that line as the height of the Equinoctiall above that plain comes unto, and muſt point up into the Equinoctiall Circle it ſelfe.

It

. It must therefore here be supposed that the situation of the plain, with such things as are thereon depending, are known. Such are these that follow.

1 The plains reclination or inclination and declination.
2 The position of the Substylar, or plains proper meridian
3. The elevation of the Pole above the plain.
4. The plains difference of Longitude from your Meridian.



These things are to be found by the common wayes of making of Dials upon plains, which need not here be repeated, but shall be supposed to be already known, and placed in their true positions upon the plain. Let A B be the

proper Meridian of the plain truly placed, and A D the Index ſtanding over it, and pointing up into the Equinoctiall. Let the degrees of the difference of the plains longitude be C L, and let the point L ſtand from C upon the right Coaſt according to the exigence of the plain. Then for drawing and dividing the line that is to give the houres, do thus.

1. Suppoſing A to be the point of the Equinoctiall (in the Zodiacall motion of the Index) through that point draw R A S perpendicular to B A C the proper Meridian; and upon A as the center, and to any convenient extent, deſcribe the Circle R C S, in which, C L is to be ſet according to the difference of Longitude, as was before mentioned. So that L is the point from whence you muſt begin to divide your Circle, for from L is the point of the houre 12 deduced. Therefore,

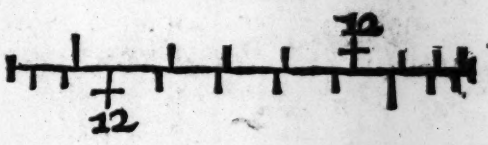
2. Divide your Circle from L into 24 houres at *a, b, c, d, e, f, &c. l, m, n, o, &c.* and from each of theſe points let perpendiculars fall upon the diameter R S, as L *m*, *a n*, *b p*, *&c.* the ſame Perpendiculars ſhall divide the Diameter into the houres required: *m* ſhall be the point of 12, becauſe it falls from L, the point of the difference of Longitude: *n* and *o* ſhall be the next houres to 12 on both ſides: *p* and *q* ſhall be the ſecond houre points on both ſides 12, and ſo the reſt in their orders.

But then in theſe Dials, when the difference of Longitude falls not juſt upon an hour (as very ſeldome (and then but caſually) it doth) the line R S will be croſſe divided as you ſee it in this example, for *e* R *u* is one hour, and unequally broken and ſet upon the Diameter R S: ſo *t* S *o* is the ſpace of 5 houres; and the points *t* and *o* ſtand croſſe or diſtant one from the other, and are not coincident; which I ſay muſt alwayes happen when the difference of Longitude is

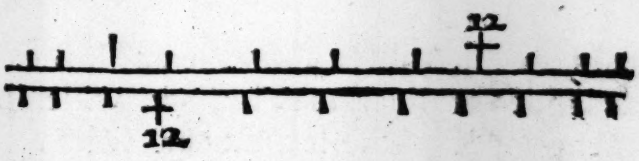
not

not equall to one or more juſt full houres.

3. In theſe croſſe houres (for ſo I may call them) you may divide each ſide of the line ſeverally, as thus:



Or elſe you may make a double line in this manner, ſuppoſing the fiduciall line to be the white that lies intire and undivided betwixt them.



This kinde of Diall will be ſomwhat difficult in the uſe, becauſe of this croſſe diviſion of the houres. Yet I thought beſt not to omit it, becauſe it is the ground of the next Caſe which will be more uſefull.

Concerning the Zodiac and the Index.

FOr the limitation of the Zodiac, let A R or A S be as Radius. To that Radius let A F be the Tangent of $23\frac{1}{2}$. This Tangent is to be augmented according to the proportion that the Radius bears to the Secant of the complement of the angle D A B, which is the elevation of the Equinoctiall above the plain: That is,

As the Radius, To the Secant of the Poles elevation above the plain (which is the ſame with the ſaid complement;) So is the Tangent of A F, to the line A B ſuppoſe. Therefore now A B is the length of halfe your Zodiac, and muſt be taken as a Tangent of $23\frac{1}{2}$ *gr.* (or as a Scale of $\frac{4348}{10000}$ equall parts) by which you may inſert the Moneths or Signes as is before ſhewed, *Pag.* 4, 5, &c. Theſe muſt be ſet on and charactered as the nature of the plain ſhall require them to be ordered.

The Index though it move, yet muſt alwayes lie juſt over the proper Meridian A B, and muſt alſo keepe the angle D A B unchanged, and muſt be moved from B to A, and ſo to B, as the time of the year ſhall require. Or the Index may ſtand and the Diall move upon the line B B, as the manner of theſe kindes of Dials may be, and which have been too often mentioned. The ſecond caſe follows.

¶ 2. *How to make a Diall upon a finite ſtreight line, drawn upon any plain, the Index being ſo ordered, that it point up into the Equinoctiall Circle, and into a juſt hour point in the ſame Circle.*

AS before, ſo here, it muſt be ſuppoſed that the ſituation of the plain with the other things (beforementioned) which depend thereupon are known and placed upon the plain. And the matter muſt be ſo ordered, that the Index muſt both looke into the Equinoctiall Circle, and alſo it muſt point to ſome juſt hour therein, that ſo one diviſion of the Diall line may very well ſerve for accounting the houres both wayes, the whole houres and parts

parts upon one ſide juſtly correſponding to the juſt houres and parts upon the other ſide. This will be for more expedite uſe than the former way could be, and no ſuch trouble nor confuſion in the numeration of houres and parts of houres, as will appear in the next Example.

In this Caſe that we are now going upon, we muſt conſider theſe things.

1. How the Index is to be ordered, ſo as that it may look up into ſome juſt houre point of the Equinoctiall?
2. How the line of the Diall or houres (the horologicall line) is to be placed, and limited and divided?
3. How the Zodiac is to be placed and limited?

℄ Firſt, for the Index: The beſt way will be to finde what Declination and Reclination (in reſpect of the Meridian and Zenith of the plain) the houre point (into which the Index muſt point) hath. And that is done by theſe two Rules.

1. As the Radius, to the Sine of the Equinoctials altitude above the plain:

So is the Co-ſine of the diſtance of that houre point from the Meridian of the plain, to the Co-ſine of the Reclination; or to the Sine of the elevation of the Index above the plain.

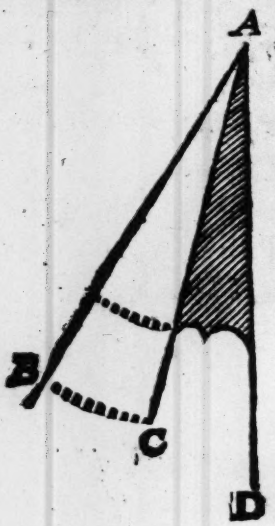
2. As the Radius, to the Sine of the Poles altitude above the plain:

So is the Co-tangent of the former diſtance (of the intended houre point from the Meridian of the plain,) to the Co-tangent of the declination of the Index from the Meridian of the plain. Or thus, 2.

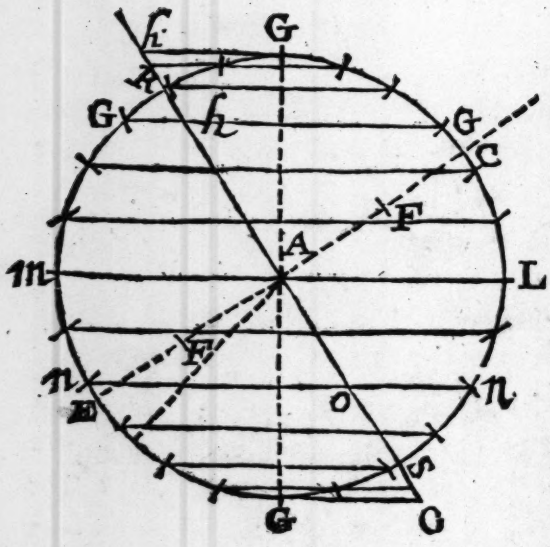
As the Sine of the Poles altitude above the plain, to the Radius, So is the Tangent of the former diſtance, to the Tangent of the declination of the Index from the plains Meridian.

Thus

Thus, ſuppoſe A B were the proper Meridian of the plain, make the angle B A C on the right Coaſt, and equall to the declination of the Index (now found) and elevate A D juſt perpendicularly over A C, to the angle D A C equall to the elevation of the Index above the plain, and ſo you ſhall place the Index in a juſt poſition, that it ſhall looke up into a juſt houre point of the Equinoctiall. That is the firſt thing.



℄ Secondly. The Horologicall line is to be ſet for poſition as it was before in the precedent Caſe, namely, perpendicular to the proper Meridian, as in the former and this Scheme you ſee R A S.



Then again, this line which in the former figure was equall to R S the Diameter of the Circle (or two aſſumed Radiuſſes) muſt now in this caſe be enlarged, according as you have ordered your Index to wrye from the proper Meridian of the plain to any other juſt houre; as in this figure it is made to be diſtant from that proper

proper Meridian unto the houre of 12: that is, it is ſuppoſed to be turned ſo, as to looke into our 12 a clock point in the Equinoctiall: which point of 12 in the former figure was noted at L, and ſo in this figure let it beſuppoſed again. I ſay, let it be ſuppoſed that (becauſe the former Horologicall line was croſſely divided, and therefore untoward for uſe) this way that is now ſpoken of ſhall be to take away that inconvenience in uſe which was in the former. And therefore ſuppoſe the Style or Index to be wryed from the proper Meridian of the plain to the Meridian of the place, or to the point of 12. It may as well be put to any other juſt houre, as to 12, but be it ſo in this Example, and let the point be L ſelected from all the reſt.

From the ſelected point L, draw the diameter L A M, and from the ſelected point L divide the Circle into 24 equall parts or houres. Then from each two houre points correſpondently diſtant on both ſides the Diameter L M draw right lines, as G *h* and *n* O, and G O, which will be all parallel to the Diameter L M. Draw theſe lines (I ſay) and continue them untill they meet with the horologicall line R A S, ſufficiently prolonged both wayes. By this draught thus made, the horologicall line R A S ſhall be both prolonged to *h* O, and alſo divided juſt as a line of Sines, ſo the parts of it are in the ſame proportion that the parts of the Diameter G A G are, which are Right Sines both wayes from the center, or Verſed Sines from G through A to G.

☞ Note that here (as formerly) you may aſſume the Circle of what extent you liſt, and ſhall finde moſt fitting your purpoſe.

It is plain then by this Example, Firſt, that the Radius

of

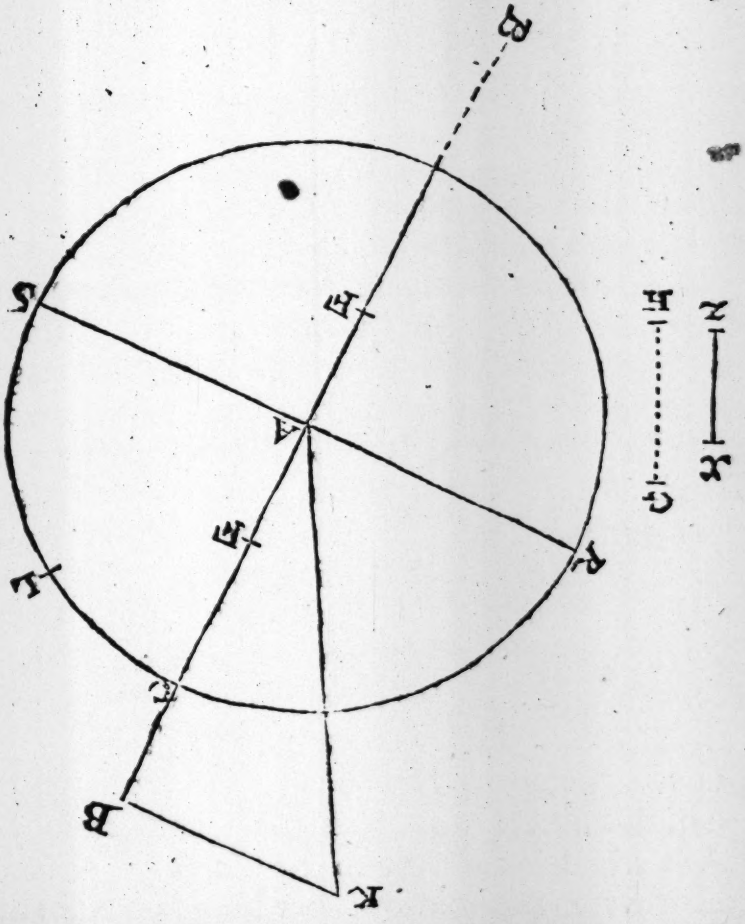
of the Circle A R, is to be enlarged, according to the secant of the Equinoctiall distance between the proper Meridian of the plain, and that just hour (whatever it be) into which the Index is made to point. As you see that arke to be here L C, or G R, or G S, whose secant is A *h*, or A *o*, in respect of the assumed Radius A R. And secondly, that *h o* thus enlarged is divided like a double line of Sines, as it ought to be.

And for numbering the houres, if A be 12, and the Index look toward the South, then must *o* be 2, and the other *o* must be 6; and the first *o*, 10 at night. And *h* must be 9 in the morning; the other *h*, 6 in the morning; and the first *h* 3 in the morning.

But if the Index had not pointed up into 12 at L, but into some other hour as P, then must a Diameter have been drawn at first from P to the center A quite through, and all the houres parallel to P A, and then the horologicall line would have been thus numbered with 7 at the two extreams, and 1 in the midst at A.

And here is one speciall thing to be noted (as formerly *Pag.* 125) but this here is alwayes so, and in all Oblique Horizons. That in our Climates where the dayes are in Summer longer than 12 houres, the shadow of the Index doth really go forward and backward. As to make it plain. If the Diall were described upon an Horizontall plain (for instance) and it were our longest day, then the shadow of the Index would

would begin at 4 a clock (figured below the line) and would go thence towards the left hand to 5, 6, and 7. At 7 it would return back towards the right hand through 8, 9, 10, 11, 12, 1, 2, 3, 4, 5, 6, untill 7, and then being arrived at 7, the utmoſt point on the right hand, it will come back again towards 8 and 9 to the left hand. This for the placing, limiting, and dividing of the horologicall line.



¶ Thirdly, Concerning the Zodiac how it muſt be placed and limited, conſider of theſe things. The Zodiac (in

this caſe of wrying the Index from the plains proper Meridian) muſt be augmented in length, and changed in ſituation from what it was in the former caſe where the Index looked up into the plains proper Meridian. Yet I will here firſt begin with that way ſo far as it goes, and then proceed to what is further needfull. Let the Figure *Pag.* 137 be here repeated. To the Radius A R, the Tangent of 23 and a halfe is A F, and the ſame is there augmented thus.

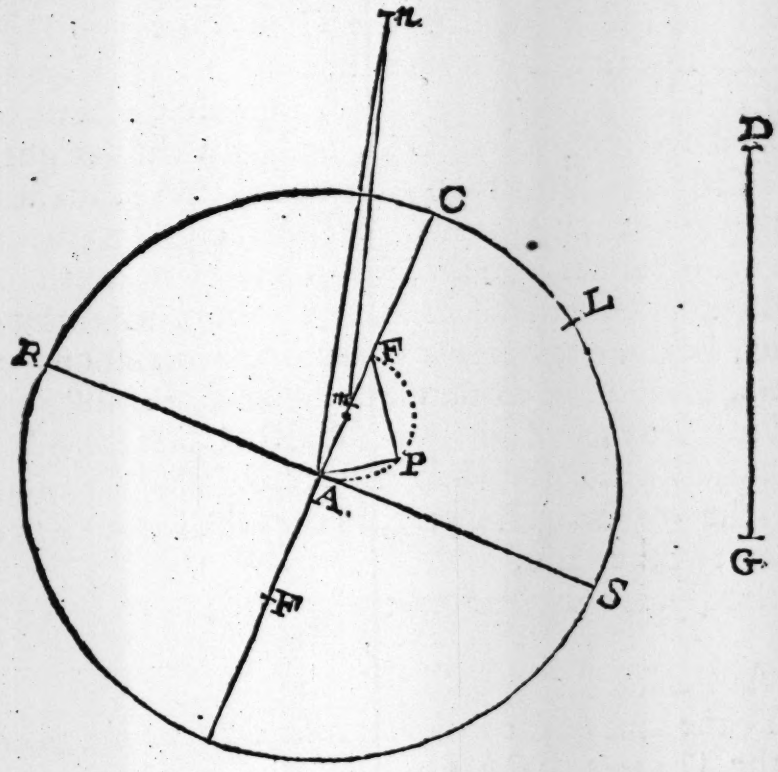
As the Radius,

To the Secant of the Poles elevation above the plain;

So let A F be ſuppoſed to be,

To A B.

So that if the Index were pointing directly to the Meridian point (in the Equinoctiall) which is proper to the plain, then the buſineſſe was at an end; for A B muſt be the length of the Zodiac, and ſtanding ſquare to R A S. But now we here ſuppoſe the Index to be wryed from that point, as much as the arke C L comes to; which turning aſide will both lengthen the Zodiac again, and turn it out of its perpendicular ſtanding to R A S. Which thing is thus to be effected. To A F as a Radius, finde the Tangent of the Poles elevation above the plain; ſuppoſe that Tangent were G H. Then ſay, As the Radius, to the Tangent of C L the quantity of wrying, ſo G H to X Z. Make B K equall to X Z, and parallel to A R, and draw A K, ſo ſhall A K be the length, and ſhall alſo give (in this poſition) the ſituation of the Zodiac. The manner how to divide it need not be repeated, becauſe it hath been often ſet down heretofore, You muſt only remember to place this line upon that Coaſt of A B which is contrary to the Coaſt of the Indexes deviation or wrying from the proper Meridian point of the plain: this work may either be protracted, or calculated, or wrought Inſtrumentally, as ſhall beſt be liked of. Ano-



Another way I will here adde to do the ſame work, which may perhaps be not inferior to the former. Let all things preparatorie in the former Figure, be here again repeated, R A the Radius, and A F the Tangent of 23 degrees and a halfe to that Radius: then to A F as Radius, finde the Sine and Co-ſine of the Poles elevation above the plain: let F P be the Sine, and A P the Co-ſine. Make A *m* equall to A P; and from *m* draw the line *m n*, making the angle *n m* C equall to the angle B A C *Pag.* 142, and ſtanding on the contrary Coaſt, which is the angle of the declination of the Index from A C in this Figure, the proper Meridian of the plain.

Then ſay, As the Radius, is to the Tangent of the Reclination of the Index (which is the Complement of D A C (*Pag.* 142) the elevation of the Index above the plain,) So is the Sine F P to a fourth quantity, ſuppoſe the ſame to be D G: make *m n* equall to D G, and draw the ſtreight line A *n*, ſo ſhall A *n* in this Figure be equall to A K in the precedent, and the angle *n* A C be (here) equall to the angle K A B in the former. So that A *n* muſt be the length of the halfe Zodiac, and will lie in its true poſition by this work. This may be done either by calculation, protraction, or Inſtrument, as all other works may alſo be. Care muſt alwayes be had to place theſe Zodiacs on the right Coaſt from F A C, and that the Zodiac be rightly divided and charactred according to the Seaſons of the year, as they ſhall have reſpect to the nature of the plain.

Or thirdly, it may be done thus. Firſt,

1. As the Radius,
To the Sine of the Poles elevation above the plain;
So the Tangent of the Equinoctiall diſceſſion or wrying,
To the Tangent of the Declination of the Zodiac; which is the angle *n* A C in this Figure, or B A K in the former.

2. As the Co-ſine of the diſceſſion, or Equinoctiall wrying,
Is to the Radius;
So is the Tangent of the Poles elevation above the plain,
To the Tangent of another Arke.

3. And, As the Radius,
Is to the Secant of that arke (or as the Co-ſine of that arke to the Radius;) So

So is the Tangent of 23½ *gr.*
To a number.

If now you make the Radius of the Circle first assumed, namely R A or A S to be a Decimall scale, and out of that Decimall scale do take this number, the same shall give the length of the Zodiac A *n* in this figure, or A K in the former. The division of this Zodiac now it is thus placed and limited, must be done by the Tables and directions in the 4 and 5 Pages. For A *n* must be taken as a Tangent of 23½ *gr.* or as the number 4348 of a Decimall scale of 10000 parts.

Thus much for this kinde of Diall upon a streight line, both crossely and evenly divided.

A DEMONSTRATION of the former way.

IN *Pag.* 28, *Note* 5, there is mention made of Polar plains or right Horizons, that in them, the Ellipsis closeth up into a right line. That right line is here the line that we have to do withall. For we here suppose alwayes that the Index pointeth up into the Equinoctiall Circle; and the Index we alwayes suppose to be a Zenith line, and therefore the Horizon proper to that Index as a Zenith line, must needs make right angles with

Then ſay, As the Radius, is to the Tangent of the Reclination of the Index (which is the Complement of D A C (*Pag.* 142) the elevation of the Index above the plain,) So is the Sine F P to a fourth quantity, ſuppoſe the ſame to be D G: make *m n* equall to D G, and draw the ſtreight line A *n*, ſo ſhall A *n* in this Figure be equall to A K in the precedent, and the angle *n* A C be (here) equall to the angle K A B in the former. So that A *n* muſt be the length of the halfe Zodiac, and will lie in its true poſition by this work. This may be done either by calculation, protraction, or Inſtrument, as all other works may alſo be. Care muſt alwayes be had to place theſe Zodiacs on the right Coaſt from F A C, and that the Zodiac be rightly divided and charactred according to the Seaſons of the year, as they ſhall have reſpect to the nature of the plain.

Or thirdly, it may be done thus. Firſt,

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To the Sine of the Poles elevation above the plain;
So the Tangent of the Equinoctiall diſceſſion or wrying,
To the Tangent of the Declination of the Zodiac;
which is the angle *n* A C in this Figure, or B A K in the former.

2. As the Co-ſine of the diſceſſion, or Equinoctiall wrying,
Is to the Radius;
So is the Tangent of the Poles elevation above the plain,
To the Tangent of another Arke.

3. And, As the Radius,
Is to the Secant of that arke (or as the Co-ſine of that arke to the Radius;)

So

So is the Tangent of $23\frac{1}{2}$ *gr.*
To a number.

If now you make the Radius of the Circle first assumed, namely R A or A S to be a Decimall scale, and out of that Decimall scale do take this number, the same shall give the length of the Zodiac A *n* in this figure, or A K in the former. The division of this Zodiac now it is thus placed and limited, must be done by the Tables and directions in the 4 and 5 Pages. For A *n* must be taken as a Tangent of $23\frac{1}{2}$ *gr.* or as the number 4348 of a Decimall scale of 10000 parts.

Thus much for this kinde of Diall upon a streight line, both crossely and evenly divided.

A DEMONSTRATION of the former way.

IN *Pag.* 28, *Note* 5, there is mention made of Polar plains or right Horizons, that in them, the Ellipsis closeth up into a right line. That right line is here the line that we have to do withall. For we here suppose alwayes that the Index pointeth up into the Equinoctiall Circle; and the Index we alwayes suppose to be a Zenith line, and therefore the Horizon proper to that Index as a Zenith line, must needs make right angles with

with the Equinoctiall Circle, and muſt therefore be a right Horizon or Polar plain.

When the Index is pitched in a true poſture, all the houre points of the Equinoctiall Circle muſt be ſuppoſed to have lines iſſuing from them all parallel to the Index. This is a generall truth in the whole courſe of the Ellipticall Dialling, Wherefore,

Firſt of all, Theſe lines will (in this caſe) fall all upon the plain of the Equinoctiall; and becauſe the common ſection of any two plains muſt be a right line, therefore it is that all theſe lines ſo iſſuing, will fall upon one and the ſame ſtreight line, namely, whenſoever the Equinoctiall meets with or cuts any other plain. Hence comes it to be *Rectilineal Horologiography*, being performed upon a plain.

Secondly, Becauſe they are all parallel to the Index, therefore they muſt all be parallel to one another; and becauſe they come originally from a Circle, and are parallel, they will all alſo keep diſtance one frō another as the Sines in a Circle do.

Thirdly, Becauſe the Index moves alwayes in a parallel poſition to it ſelfe, and would ſhew the houre upon the circular diviſions of the Equinoctiall Circle (at all times of the year, that is, when this Equinoctiall is made to repreſent all other parallels of Declination) it muſt follow that the Index when (the ſhadow of) it falleth upon any one ſuch point, it muſt alſo fall upon the whole line that iſſueth through that point. The reaſon is, becauſe the line is alwayes parallel to the Index, therfore if it touch one point it muſt ſhadow the whol.

Fourthly, Hence will follow, that any line drawn upon the plain of the Equinoctiall, croſſing thoſe forementioned parallel lines, ſhall be a line of Sines (or a double line of Sines, if you will rather expreſſe it properly) and if it paſſe through the center of the Equinoctiall Circle (where the Index alſo

doth

doth alwayes passe) then is such a line one of the Dials that we here are to deal with. Because every plain is taken for a great Circle cutting the Equinoctiall in the center. And the divisions of this line(the Sinicall divisions)must be the houre points, as is said before.

Now all that we have here to say is the making good of the former rules of limiting out and placing the houre line, the Zodiacall line,and the Index. If we therefore(in all cases) suppose the Index to be a Zenith line, and then an Horizontal plain to be placed perpendicular to it,this plain must be the proper Horizon to that Index (or Zenith line) and must (in these Cases here handled)go through the Axis of the world (a part of which I must call the primary Zodiac) and will cut the Equinoctiall plain in a right line placed perpendicularly to the Index, which I call the primary horizontall line.

And again, all that is done in other plains (not perpendicular to the Index) must be imagined primarily (or originally) to be deduced from this proper Horizontall plain.

First therefore, for the houre line. If the Index lie in the proper Meridian of the plain (as is supposed in the first of the former Cases) then the Diameter of the Circle that is at first assumed,serves for the horologicall line without any alteration,because the proper Horizon, and the plain upon which you work, do (both of them) cut the Equinoctiall in one and the same line,which is to be the horologicall line. And therefore in plain reason,so much of the Equinoctiall as the Index is wryed from this proper Meridian of the plain, so much of the same Equinoctiall must the proper Horizon be wryed with it, and consequently, so much will be between the proper horizontall line and the horologicall line of the plain, but still both these lines will continue upon the same plain of the Equinoctiall, and consequently they must in both

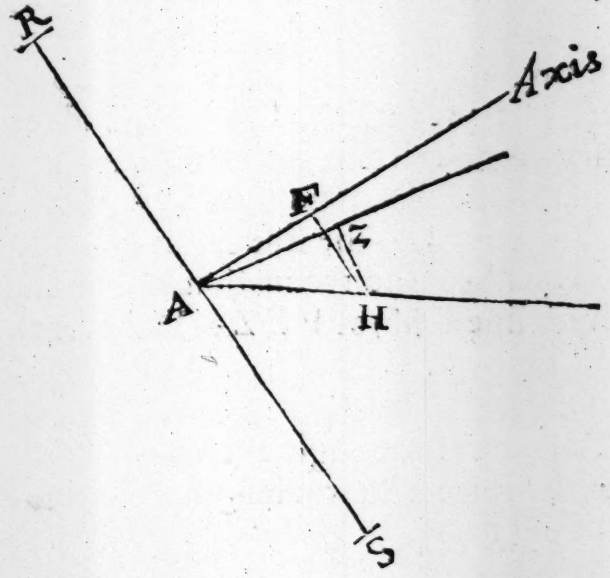
cases

caſes be one and the ſame line, namely that which is made by the projection of the Equinoctiall Circle upon the plain, only it muſt be augmented according to the proper horizontall lines departure from the ſection of the plain with the Equinoctiall, that is, according to the wrying of the Index, as is plain enough by what is ſaid in the 142 *Pag.* And ſo for the diviſion of that line in the ſame Page. For G G and *h o*, do both lie in one and the ſame plain of the Equinoctiall: and all the projecture muſt be made parallel to the Index, whence *h* A is the ſecant (to G A Radius) of R G or C L, the wrying of the Index.

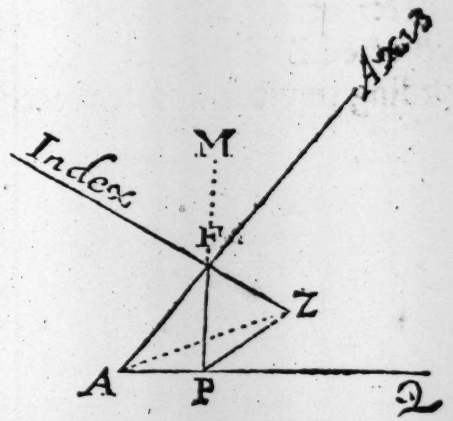
Then for the Zodiac, you are to deduce it from the Axis which is perpendicular to the Zenith line or Index: and from ſo much of it as containeth the Tangent of 2 3½ *gr.* to the Radius G A. Now though the Index do keep the proper Meridian of the plain, yet the Axis is elevated above the plain. And becauſe the projecture of that Tangent or part of the Axis muſt be parallel to the Index, therefore look what elevation the Axis or Pole of the World hath, to ſuch a Secant of the Radius equall to the Tangent of 23½ before mentioned muſt the Zodiac be extended. By which means the Index keeps the ſame ſituation and diſtance from the Equinoctiall plain that it would do if it moved according to the proper and primary Tangents upon the Axis, and no otherwiſe. And ſo doth the former enlarging of the horologicall line produce the like effect, namely, that the Index doth upon that enlarged line ſhew the ſame houres that it would do upon the proper horizontall line.

Then for the Zodiac to a wryed Index, it is both diſplaced and enlarged too, according as right lines drawn through the diviſions of the Axis, and parallel to the Index, would make a projection of it. According to which, there are three wayes given. The

The first makes A F equall to the Tangent of $23\frac{1}{2}$ to the Radius R A, to be Radius, and to that Radius findes F H, and to that again as Radius, finde H *Z* the Tangent of wrying. And so A *Z* is the Semizodiac placed and enlarged.



The second makes A F as a Radius, and to it findes F P the Sine, and A P the Cosine of the Axis his elevation above the plain. And then this line F P being perpendicular to the plain, it stands as the proper Zenith line of the plain. And becauſe we are to caſt all according to



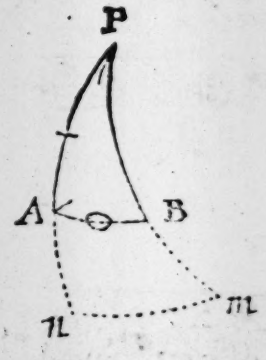
X the

the lying of the Index, therefore what reclination from the plains proper Zenith, and declination from the plains proper Meridian the Index hath, the ſame muſt the projection (or projecture) of the line F P have. That is, we may ſuppoſe the Index, or a line paral el to the Index (in his true poſture) to paſſe through the point F, and then we are to inquire where it will ſtrike through the plain. That is to ſay, it muſt looke into the ſame Coaſt that the Index doth, and ſo the angle Z P Q being made equall to the declination of the Index from A Q the proper Meridian line, and the line P Z drawn, it is certain enough that the projecture of the point F muſt be upon the line P Z. And to know where, becauſe F P Z is a right angle, and the ſide F P is known, with the angle I F M (equall to the reclination of the Index from the plains Zenith line F M) or P F Z; Therefore,

As F P Radius,
To P Z the Tangent of the angle P F Z;
So is F P in the former known length (found to A F Tangent of 23½ *gr.*)
To P Z.

Therefore Z is the point terminating the extremity of the projected Zodiac, and ſo A Z muſt be the Semizodiac, according to what was delivered in the ſecond way *Pag.* 147.

The



The third way resolves a Spherical rectangled Triangle, made between the proper Meridian of the plain P A, the plain it selfe A B, and the Meridian in which the Index lyeth, or into which it pointeth, P B. In which three quantities are known. P A the altitude of the Pole above the plain. The angle at A a right angle. And the angle at P equall to the arke of the Equinoctiall or wrying of the Index from the proper Meridian of the plain. And there is first required A B.

As the Radius P *n*,
To the Tangent of (*n m* =) P;
So the Sine of P A,
To the Tangent of A B, = *n* A C, *Pag.* 147,

Then secondly, the arke P B is required, and that is wrought by the second work, *Pag.* 148, which in the second Figure *Pag.* 153, may be understood to be the angle F A Z, Then because A F Z is a plain Triangle rectangled at F, and the angle F A Z is now known, and the side A F (equall to the Tangent of $23\frac{1}{2}$) it will be required to finde A Z in the same parts. Therefore in the third work (*Pag.* 148) it is said,

As A F, Radius, To A Z, Secant of F A Z;
So is A F in parts, (as a Tangent of $23\frac{1}{2}$,) To A Z in the same parts.

And so the Zodiac is both placed and limited.

APPENDIX.

IT hath been forwerly ſhewed (in the VIII. Section) how to make the Ellipticall Diall to any Index however placed, and to any Superficies flat or curved. That Doctrine will ſhew how to project this kinde of Rectilineall Diall (and the former Circular Diall too) onely I ſhall adde a word or two to ſhew that that way will produce a ſingle line in this caſe, and ſuch a line as muſt anſwer to a double line of Sines.

1. See the 6 and 7 Propoſitions *Pag.* 95, 96. The firſt of them is to finde the Horizontall ſpaces. And in this caſe (becauſe the Index lookes alwayes up into the Equinoctiall Circle) the Latitude of the Horizon proper to this Index line, is nothing. So that,

As the Sine of the Poles elevation, which is nothing,
Is to the Radius;
So is the Tangent of each houre from the proper Meridian of the Index,
To the Tangent of an infinite length: [For ſo it muſt be becauſe the firſt term is oo.]

Which infinite Tangent is belonging to 90 *gr.* therefore it will follow that all the houres and each of them are 90 *gr.* from the proper Meridian of the Index: that is, that they

are

are all coincident into one line, which is perpendicular to the proper Meridian of the Index. This ſhews that this Dial will be a ſingle line, and that by the former generall Doctrine, Section VIII.

2. Then for the ſecond thing, that it will be a line of Sines, or (though a curved line, yet) to be thence deduced or divided, it will appear by the ſeventh Propoſition *Pag. 96.* Becauſe,

As the Radius,
To the Co-ſine of the Poles elevation; which here is the Radius;
So the Co-ſine, &c.
To the ſame term again.

For if the two firſt terms be the ſame, then the two latter muſt be equall too. And ſince the third terms are a line of Sines, the fourth terms (which are to divide the Diall line) being the ſame with the third, will be alſo ſuch as will make a line of Sines. So this is made good likewiſe.

And there may other wayes be found to effect this ſame thing upon a curved Superficies. As firſt to project the Equinoctiall line or ſection with the uneven ſuperficies, upon the ſaid Superficies: and when that is done, to lay the edge of ſome board or ruler, in the Superficies of the Equinoctiall, with the Index lying in the plain of the Equinoctiall, will (by the former Equinoctiall line drawn) direct you in, and afterwards to proceed anſwerably to the nature of the Diall, &c. But what need I to mention any ſuch thing thus obſcurely. They that underſtand the former wayes will be able to invent many more, and ſo I ceaſe from further troubling my ſelfe or the Reader. One Propoſition more muſt here

here be added, which conduceth to this *Rectilineal Horologiography*, namely:

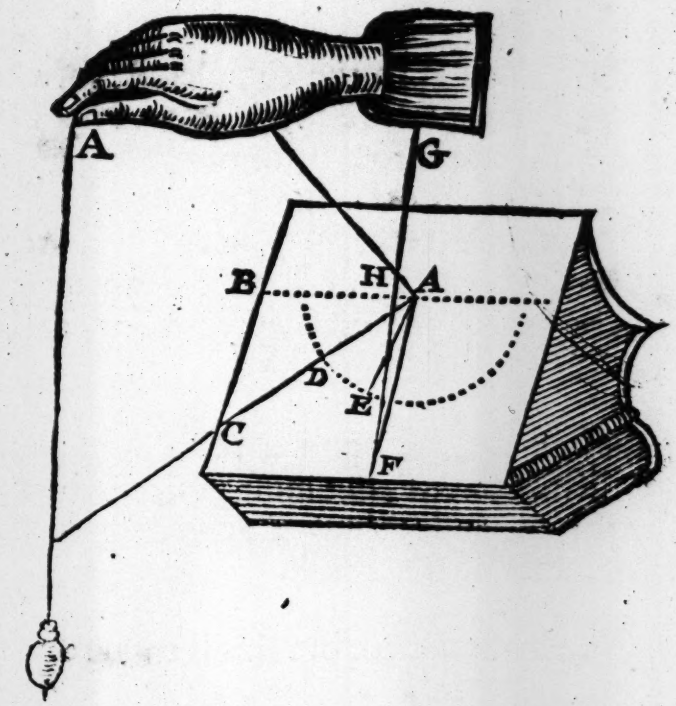
How to lay a line that ſhall point up to any aſſigned place or point in the heavens.

THis is uſefull for the laying of an Index to any condition that ſhall be required: namely, ſo as to cut through any juſt houre, either in the Equinoctiall Circle, or any other Circle in the heavens.

The firſt work muſt be to finde what Reclination and Declination the ſaid point ſhall have in reſpect of our own Zenith and Meridian. This is an eaſie Sphericall work, and therefore I ſhall omit it. Only note, that the Reclination here mentioned is the diſtance of it from our Zenith; and the declination is, what Azimuth from the Meridian the ſaid point fals into.

The next work is, how to lay or ſtretch a line to any given Declination and Reclination. The way that for the preſent I think on ſhall be this.

Firſt, Aſſigne any point from which you will have that your line ſhall riſe, as at A, then by a perpendicular threed caſt a ſhadow through A, as C A, and draw therethrough an obſcure line: and having before drawn an horizontall line through A, as is B A; apply ſome plain board or paſtboard to that line B A, and upon it project with your eye the Verticall C A by your perpendicular threed (you need not



not be over curious in holding your paſtboard level.)

Afterwards, knowing what Azimuth this is (which you may finde by taking the Suns altitude juſt when the ſhadow C A was drawn) you may upon your paſtboard ſet off (from it) your Azimuth of the lines declination, ſuppoſe it to be A E. Then again applying your paſtboard to his former true poſition, with your perpendicular threed, you may transfer (or project) A E from the paſtboard to the plain: ſuppoſe one point of that transferred Azimuth were at F, then draw the line A F, which is the ſection of that Azimuth (with the plain) in which Azimuth the Index or ſtreight line muſt lie,

There-

Therefore you must set up an erect line or threed from some point of the line or Azimuth A F, (suppose from F, and let that line or threed be F G) and the same being fixed (or projected on some fixed thing) you may then elevate your Semicircle and Ruler from A to the complement of the lines reclination (that is to the lines elevation above the Horizon) and where the Ruler cuts through, or points at the Azimuth F G, as suppose at H, there is the place or point through which the line must be stretched. Therefore AH represents this line thus situated, and a threed so extended and fixed will be a guide by which you may lay your line, and fit it to that posture.

℄ If this be not done upon a plain Superficies, you cannot then draw A F, but must project it by a perpendicular threed, and so draw it according to that projection or tract of the threed.

Other wayes may be added, but this is enough.

Another Note concerning this Rectilineall Horologiography, and Circular too.

IN the *69 page* it is said that it is not possible that the Index of an Elliptical Diall should be parallel to the plain of the Diall. Which assertion is most true of an *Elipsis quatenus propriè Ellipsis*. But if we will grant that a streight line is the narrowest of all Ellipses (which to affirm is improper) for it is rather one of the termes of an Ellipsis as a Circle is the other, and termes of quantities cannot be homogeneall to the quantities themselves) then we may here say that

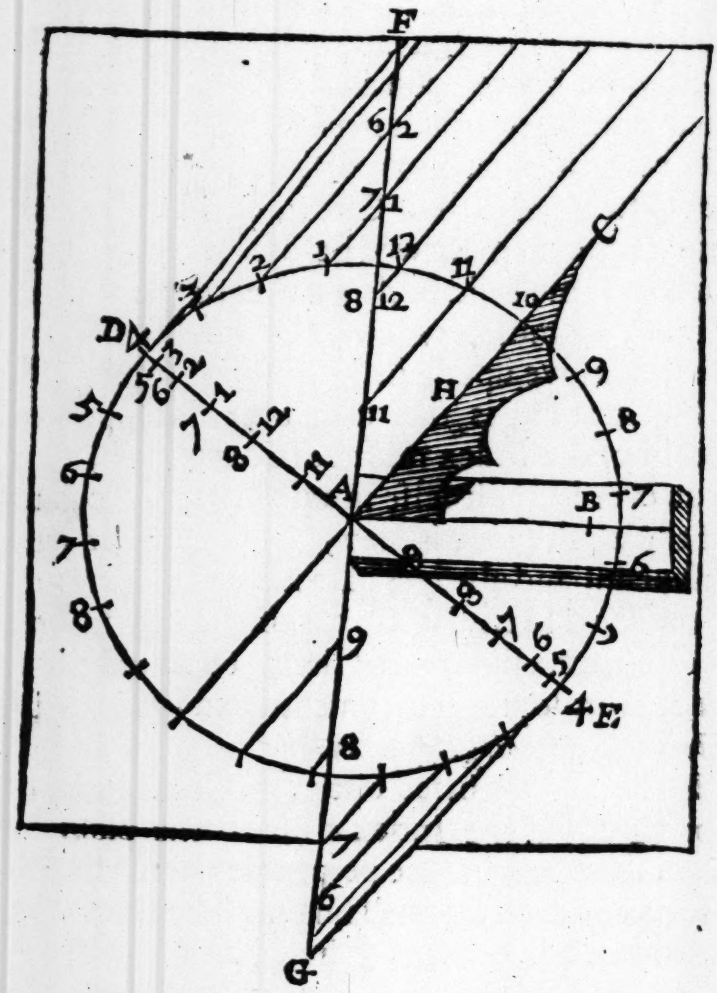
that in this caſe the Index may be parallel to the horologicall plain.

The ſumme is, That upon an Equinoctiall plain (and not upon any other) the Index may lie parallel to the plain, and ſhew the houre upon a double line of Sines deſcribed as formerly hath been ſhewed.

And to effect this, you muſt firſt lay a plain every way anſwerable to the Equinoctiall Circle, which to do is eaſie, and hath (in ſumme) been ſhewed before. Upon ſuch a plain you muſt firſt ſet ſome ſolid body parallel to the Axis of the world, which body muſt ſerve to beare the Index, and alſo for the Index to move upon, in a moſt juſt paralleliſme of the Axis. My meaning is, that what ever that ſupporter be, yet the motion of the Index muſt be ſo contrived, that the ſaid Index do ever keepe it ſelfe in a juſt perpendicularity to the Axis of the world; that is, in a juſt paralleliſme with the Equinoctiall plain; and alwayes alſo it is to be kept pointing to one and the ſame Meridian Circle of the world, and this Meridian is to be ſome juſt houre Circle, to avoid the croſſe diviſion of the Horologicall line, mentioned in the firſt Caſe of this *Rectilineal Horologiography*.

The Index being thus fitted both for Coaſt and motion, you are to bring down the Index cloſe to the plain. And upon the plain draw a right line perpendicular to the fiducial line of the Index (which fiduciall line muſt be ſuppoſed now to lie and move in a juſt houre Circle, as was before preſcribed.) This line ſo drawn ſhall be the Horologicall line. Let this plain repreſent an Equinoctiall plain, and let A B be the ſupporter, A C the Index, D A E the Horologicall line perpendicular to the Index A C, and ſuppoſe A C (upon the plain) to be any juſt houre, as 10 in the forenoon.

Then to any Radius as A D, deſcribe a Circle, and from



10 at C, divide your Circle into 24 equall parts, at 11, 12, 1, 2, 3, &c, ſo ſhall the houres of 4 and 4 fall upon the juſt perpendicular Diameter D E.

For

For the houre points.

You are here left to your choiſe to take which (of three wayes) you like beſt. Either,

1. Theſe points in the Circle may ſerve for the houre points without any more draughts, and then this will be another *Circular Diall*, differing from thoſe that were handled before in Circular Dialling.

2. The perpendicular Diameter D E may have the hours inſerted by drawing lines from each pare of houres equally diſtant from D and E houre points of the Circle, parallel to the Index C A, and ſo you ſhall have the Diameter D E divided like a double line of Sines (unequally) at 12, 11, 1, 2, 3, and 10, 9, 8, &c.

3. You may likewiſe (if you allow not the two other wayes) draw any line as F G, and by lines drawn through the houre points of the Circle, all parallel to the Index CA, the ſame line F G ſhall be divided as a double line of Sines, at 12, 1, 2, &c. and 11, 10, 9, &c. and will ſhew the houre as the other do, and the two extream parallels 4 F, and 4 G, ſhall limit the length of the line F G.

☞ *Upon this Circular way Note thus much.*

That though the Index A C ſhould not lie upon a juſt houre, but otherwiſe accidentally, yet becauſe the houre points are upon a Circle, the houres will be diſtant from each other, and not breed that diſtraction in computing that was before noted neceſſarily to fall upon the ſtreight horologicall line. And ſo you are left at liberty to ſet your Index how you will, only ſo as ever to looke into one and the ſame

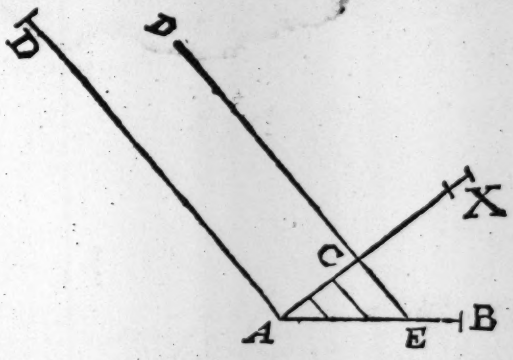
Meridian Circle. But you must then be carefull to place some one houre line true, so as to answer to some just houre circle in the heavens, which upon this Equinoctiall plain (when the Axis is once truly placed) will be easie. For if the Axis give a shadow, and you at the same instant time (noting the shadow) do observe the houre, that shadow will represent the same houre. If therefore upon that shadow line (as a Diameter) you describe a Circle, you may (from the intersections of the said line, with the Circle) set off any one full and just houre, and then from that just houre you may divide the Circle into the 24 houres. This equall setting of the Index is allowable upon the Circle, but not upon the right lines D E or F G, for in them there will be confusion of parts, which in the Circle are distant.

Note further, that you need not make the Center of the horologicall Circle just in the point A, where the extremity of the Index which came down upon the plain, but you may make it in any point where the Index A C will touch the plain, as at H, or in other like places.

Concerning the Zodiac.

You must account the Semidiameter D A of the horologicall Circle to be as Radius. And to that length (and none other) you must make the length of the Semizodiac A B upon the Axis to be the Tangent of 23 and a halfe, and by that Scale of Tangents you must put in the Sines or moneths as hath been often shewed before. And whereas I have hitherro said that the Index must move upon the Axis, and agree to a Zodiac thereon inscribed, it must be understood that in some sense this is necessary, but in some sense not so. As thus, The Index D A or D E, must alwayes move perpen-

A X the Axis.
A C the Zodiac.
A D the Index,
A B another ſupporter differing from the Axis.



pendicular to the Axis A X. But it is not tied to move upon the Axis it ſelfe. It may move according to any line that lies in the ſame plain with the Index D E and the Axis A X, that is, it may move according to the line A B, which we here ſuppoſe to be in the ſame plain or Meridian with A D and A X. This condition is alwayes requiſite, and it muſt ever keep one & the ſame angle with the right line A B, and ſuch an angle that may keepe it alwayes perpendicular to the true Axis, that is, parallel to the Equinoctiall plain. And this being obſerved, you may inſert the Zodiac upon the line A B, but it muſt be proportioned from the Axis A X, thus; As A C Radius, to A E the Secant of the angle C A E, ſo is A C the Tangent of 23 and a halfe (in reſpect of the Radius of the horologicall Circle,) to a fourth quantity; the length whereof gives A E. And now this line A E muſt be eſteemed as a Tangent of 23 degrees and a half, and by it muſt the Semizodiac or halfe year be put in, as hath been ſhewed formerly. So this is done alſo, For the Index will move upon A E, according to the parts upon A C, as it is bound to do. Only note that theſe Dials upon the Equinoctiall plains can ſerve but halfe a year upon one ſide, & therefore for the other halfe year you muſt do the like work upon the under ſide of the Equinoctiall plain. The

work

work I say is like without any reall difference, and therefore there will need no more words concerning it.

For DEMONSTRATION of these things.

THere needs nothing to be added more than what hath formerly been done for Rectilineal Dials. For what is done there in the proper Horizon (proper to the Index I mean) by a line of Sines, is here expressed by the line of Sines D A E, *Pag.* 162: only there, all the lines issuing from the Equinoctiall houre points did meet with the proper Horizontal plain, and did thereon create a single line of 180 Sines, and so the Equinoctiall Circle standing towards the eye (being infinitely removed from it) edgewise is projected upon his own diameter, and appears nothing else but as a Diameter (or streight line) to the eye. But here the same forementioned parallel lines issuing from the houre points of the Equinoctiall Circle, and flowing out upon the plain of that Circle, do so appear in full view to the eye, because the eye stands so as fully to view the said plain and not looking edgewise upon it. When the plain stood edgewise to the eye, the eye did project it into the Diameter, but now we conceive the eye to stand only to looke what was effected upon the plain by the former Projection.

And

And further. Looke what projection was formerly made (in this caſe of the Indexes pointing into the Equinoctiall Circle) upon the Indexes proper Horizon,. and was there received by a ſtreight line, the ſame is here done by drawing the Diameter D A E, *Pag.* 162, which line muſt be ſuppoſed to be the common ſection of the Indexes proper Horizon with the Equinoctiall plain. And ſo in effect both theſe Caſes are nothing different.

Then for the line F G, the parts of it, and the points of the Circle, and the points of D E muſt neceſſarily all fall into one houre line, and all ſhew the true houre (whichſoever of them you take for your Horologicall line) becauſe as the lines iſſuing from the houre points of the Equinoctiall are all parallel one to the other, and all again to the Index, therefore if any part of the ſhadow of the Index do fall upon any part of one of thoſe lines, the whole ſhadow muſt fall upon the whole line, and conſequently the correſpondent points upon D E and F G and the Circle, will all joyntly, or each of them ſeverally, give the houre of the day. Other things are plain enough.

Of the paralleliſme of the Index and Plain.

It muſt further be noted, that an Index may be made to point up into the Equinoctiall Circle, and yet alſo be parallel to any plain whatſoever. For every plain cuts the Equinoctiall Circle ſomwhere: Now if an Index be made to lie in that common ſection of theſe two Circles or plains, then will it lie parallel both to the Equinoctiall plain and to the other plain, and it may be made to move alwayes parallel to them both, if it be moved at right angles to any line that ſhall ſtand perpendicular to the ſaid common Section.

But

But for all this, there can no ſuch Diall (as we have now ſpoken of) be made upon any other plain beſides the Equinoctiall. I ſay there can no paralleliſme of the Index to the plain be (in this kinde of Dialling) allowed, more than what is ſaid may be done upon the Equinoctiall plain.

For though the Index may be parallel to the Equinoctial and plain both, yet the Equinoctiall it ſelfe muſt make angles with all ſuch plains. And becauſe the Index is parallel to the common Section, therefore all the houre points projected by parallel lines to the Index, muſt be upon the Equinoctiall plain it ſelfe, and muſt run parallel to the line of common ſection: that is, they will all run ſo, as never to meet ſo much as with the line of common ſection (which line is upon the Equinoctiall plain) much leſſe ever to meet with any part of the plain it ſelfe, which is every where diſtant more or leſſe from the Equinoctiall, except only in the line of common ſection. So that there is no more to be ſaid of this ſubject.

FINIS.

ELLIPTICAL
Horologiography.

SHEWING

How upon any plain to draw an *Elliptical* Diall, to an Index ſet any way, by Sphericall (and not Projective) work.

Invented and written by

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ELLIPTICAL Horologiography.

Hitherto we have had the whole buſineſſe of *Elliptical Horologiography*, ſo far as that more cannot ſeem to be thought of, or required. Yet, Becauſe to any Index ſet either on purpoſe or caſually, the houres have been (formerly) found out by Projection, I thought fit here to adde another way (but for plains only) that ſhall not need that projective manner of working.

And ſo the *Probleme* will be this:

How upon any plain to draw an Elliptical Diall, to an Index ſet any way, by Spherical (and not Projective) work.

The ſubſtance of what I ſhall here ſay is moſt of it delivered before, only I muſt now ſhew what Propoſitions are to be referred hither, and how they muſt be uſed.

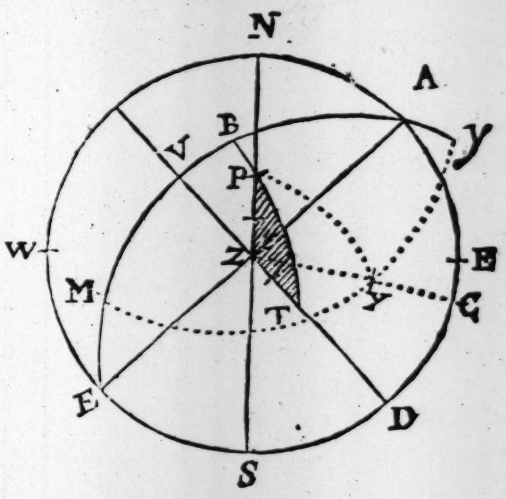
Things that are pre-requiſite to this work.

1. You muſt know the ſituation of your plain, that is, what Declination and Reclination it hath in reſpect of your own Horizon. This is to be done the ordinary way, as in all plains is uſuall.

2. You muſt know the Declination and Reclination of your Index. That is, if the Index be ſet caſually you muſt then finde out the Declination and Reclination thereof, which is ſhewed, *Pag.* 80. how it muſt be done, namely, by obſervation from the Sun, and cannot be otherwiſe performed. Or if you chooſe a Longitude and Latitude wherein to lay your Index, then muſt you (by that Longitude and Latitude given) finde what Declination and Reclination is due thereunto, in reſpect of your own Horizon: and according to this Declination and Reclination you are to lay your Index. See the Schemes *Pag.* 83,84, for by thoſe or the like you are to conceive of your Spherical work in this kinde.

3. Having thus found the ſituation both of plain and Index, in reſpect of your own Horizon, you muſt then finde what ſituation the Index hath in reſpect of the plain; that is, what Declination it hath from the proper Meridian of the plain, and what Reclination it hath from the Plains Zenith. This Propoſition hath not been handled before, but muſt be put here in this place.

Let your own Horizon be N W S E, the Zenith Z, the Pole P, and let A V E be a declining reclining plain, whoſe Declination and Reclination we now ſuppoſe to be known by,



by former rules; that is the angle S Z D (equall to the Declination) is known, and Z V or D T (equall to the Reclination) is known. So that in the Triangle P Z T, there is P Z (equal to the complement of P N, the Poles altitude,) Z T (equal to the complement of Z V the Reclination,)& P Z T (equall to the complement of S Z T, the plains Declination from the South:) therefore you may now finde the three unknown quantities; namely, P T the complement of the Poles elevation above the plain: and Z P T, the diſtance of the plains Meridian from yours, which is the plains difference of Longitude: and laſtly, Z T P the diſtance of P T the plains proper Meridian from V Z T the Verticall line of the plain. Or which three ſoever you have, you may finde the other three. As having the difference of the plains Longitude, the angle P, with the plains Latitude the complement of P T: and *P Z* the complement of your own Latitude. You may finde all the reſt. And by that means you may ſet a plain to any Latitude and difference of Longitude, that is anſwering to the Horizon of any known place in the world.

The next work is to finde what ſituation an Index (ſet up upon the plain) ſhall have to the plain, and the fundamental lines thereon deſcribed, *viz.* the Verticall line, and proper Meridian.

I ſuppoſe firſt, that the Declination and Reclination of the

the Index (in reſpect of your own Horizon) is known by the former things already ſpoken of, and from thence you may gather what is here required. Thus

Let the Index point up to X: and let Z X (the reclination from your Zenith) be known, and S Z X (the declination from your Meridian) be alſo known. Now therefore in the triangle T Z X, there are three things known.

1 T Z the Complement of the Plains reclination in reſpect of your Horizon.

2 Z X the complement of the Indexes reclination in reſpect of your Horizon.

3 Thirdly, the angle T Z X, which is the difference of the two declinations, namely of the plain and of the Index. By theſe all the reſt will be found; as namely,

1 T X, the reclination of the Index X from T the pole of the plain, which is called the proper reclination of the Index.

2 Z T X, or V Y, or rather V M, which ſhews how much the * Subindicall line lies from the Verticall line of the plain (in degrees of a Circle deſcribed upon the plain) and conſequently, becauſe P T Z was known before, therefore P T X is now alſo become known, which ſhewes the declination of the * Subindicall line from the plains proper Meridian, which may therefore be called the proper declination of the Index.

3 The angle Z X T (if it be of any uſe here) ſhews how much (in Azimuthal poſition) your Zenith Z lies from T, the Zenith of the plain upon that Horizon whoſe Zenith line is the ſame with the Index, which is therefore the proper Horizon to the Index.

* Subindicall line I call that line upon the plain which lies perpendicularly under the Index, as the ſubſtilar doth under the Stile. I mean perpendicularly in reſpect of the plain, not of the Horizon.

Or if you would ſet an Index ſo as to fit it to any aſſigned difference of Longitude, and to any aſſigned Latitude alſo, you muſt work thus.

LEt X P S be the aſſigned difference of Longitude, and P X the complement of the Latitude, into both which the Index ſhall point up in X. Becauſe the plains difference of Longitude *Z P T*, is known before, therefore the angle T P X is known. And P T the complement of the plains Latitude is alſo before known. Therefore in the triangle T P X theſe three things are known, *viz.* P X, P *T*, and the interjacent angles T P X. By which three you may finde all the other quantities: namely, *P T* X, or B Y, the departure of the Subindicall line from the plains proper Meridian: *T* X the proper reclination of the Index X from T the pole of the plain, or the complement of it (X Y) which is the elevation of the Index above the plain juſt over (perpendicularly over in reſpect of the plain) the Subindicall line: with the angle *P X T* (if there were any uſe of it) which ſhewes how much the pole of the plain declines from the proper Meridian of the Index. I ſay, it ſhewes this declination upon that Horizon (whatever it ſhould be) which ſhall be properly belonging or perpendicularly placed to the ſaid Index as the proper *Z*enith-line.

Thus the ſituation of the Index (whether caſually, or by election ſet) is found to the true coaſts of the plain it ſelf.

What remains to be done.

THe reſt of the work for making the Elliptical Diall it ſelf to the Index aſſigned, and for limiting and dividing the

the Index (in reſpect of your own Horizon) is known by the former things already ſpoken of, and from thence you may gather what is here required. Thus

Let the Index point up to X: and let Z X (the reclination from your Zenith) be known, and S Z X (the declination from your Meridian) be alſo known. Now therefore in the triangle T Z X, there are three things known.

1 T Z the Complement of the Plains reclination in reſpect of your Horizon.

2 Z X the complement of the Indexes reclination in reſpect of your Horizon.

3 Thirdly, the angle T Z X, which is the difference of the two declinations, namely of the plain and of the Index. By theſe all the reſt will be found; as namely,

1 T X, the reclination of the Index X from T the pole of the plain, which is called the proper reclination of the Index.

2 Z T X, or V Y, or rather V M, which ſhews how much the * Subindicall line lies from the Verticall line of the plain (in degrees of a Circle deſcribed upon the plain) and conſequently, becauſe P T Z was known before, therefore P T X is now alſo become known, which ſhewes the declination of the * Subindicall line from the plains proper Meridian, which may therefore be called the proper declination of the Index.

3 The angle Z X T (if it be of any uſe here) ſhews how much (in Azimuthal poſition) your Zenith Z lies from T, the Zenith of the plain upon that Horizon whoſe Zenith line is the ſame with the Index, which is therefore the proper Horizon to the Index.

* Subindicall line I call that line upon the plain which lies perpendicularly under the Index, as the ſubſtilar doth under the Stile. I mean perpendicularly in reſpect of the plain, not of the Horizon.

Or

Or if you would ſet an Index ſo as to fit it to any aſſigned difference of Longitude, and to any aſſigned Latitude alſo, you muſt work thus.

LEt X P S be the aſſigned difference of Longitude, and P X the complement of the Latitude, into both which the Index ſhall point up in X. Becauſe the plains difference of Longitude Z P T, is known before, therefore the angle T P X is known. And P T the complement of the plains Latitude is alſo before known. Therefore in the triangle T P X theſe three things are known, *viz.* P X, P T, and the interjacent angles T P X. By which three you may finde all the other quantities: namely, P T X, or B Y, the departure of the Subindicall line from the plains proper Meridian: T X the proper reclination of the Index X from T the pole of the plain, or the complement of it (X Y) which is the elevation of the Index above the plain juſt over (perpendicularly over in reſpect of the plain) the Subindicall line: with the angle P X T (if there were any uſe of it) which ſhewes how much the pole of the plain declines from the proper Meridian of the Index. I ſay, it ſhewes this declination upon that Horizon (whatever it ſhould be) which ſhall be properly belonging or perpendicularly placed to the ſaid Index as the proper Zenith-line.

Thus the ſituation of the Index (whether caſually, or by election ſet) is found to the true coaſts of the plain it ſelf.

What remains to be done.

THe reſt of the work for making the Elliptical Diall it ſelf to the Index aſſigned, and for limiting and dividing the

the Zodiacall Scale depends upon this one Rule. Namely,

To project the houre points of the Equinoctiall, and the Zodiacall Scale upon the Axis (which Zodiacall Scale upon the Axis it ſelf is made by the Tangents of 23 *gr.* and an half, to the Radius of that Sphere wherein you ſhall imagine your Circles to be) I ſay. To project (all ſuch points) upon the plain, by lines paſſing through each one of them, and all and each of the ſame lines to be drawn parallel to the Index given. This is the ſumme of what is here now to be done, and of what hath been done formerly quite through this Book. For all that is before effected upon any plain or curved Superficies, is nothing more then what I have now ſaid; namely, a determining of the true places of every ſuch (houre and Zodiacall) point, as they ſhall be projected upon the Dialls Superficies, by lines going through them, and going parallel alſo to the Index that is to give the houre. For ſo, the Equinoctiall Circle will very well ſupply every parallel of the Sun, the Index and horologicall line being rectified by the Zodiac in a true ſite one to the other, as hath been often mentioned before; And then the Index, caſting its ſhadow upon the houre point, either in the Equinoctiall or in the parallel Circle, muſt alſo caſt it upon the whole projecting line, which paſſeth through the hour point, (becauſe that line is made alwayes parallel to the Index) and conſequently upon that point of the houre, which (by the ſaid line) is carried to the Diall-Superficies. And ſo for the points of the Zodiac, they are alſo projected in ſuch manner, as that the Index moving in them (however they may ſeem to ſtand awry and out of order) ſhall alwayes cut the Axis of the World (if it were there placed) and cut it according to the Tangents of declination thereon expreſſed. And this will ſerve for a brief demonſtration of that work which is now to come afterwards.

In

In which we are first to bring down the houre points and Zodiac to the plain considered as an Horizon, and the projection of those points to be made into an Ellipsis, by lines all perpendicular to the said plain, that is, parallel to the plains proper Zenith line. Secondly, we are to project or transpose these first (both Houre and Zodiacall) points from the primary Ellipsis into a secondary Ellipsis, such as the position of the true intended Index will require: And so also the points of the Zodiac must be dealt withall.

How to make an Ellipticall Diall upon any Plain, to an Index perpendicular to the Plain.

THe first work is done before, partly by Calculation, and partly by protraction, *Pag.* 25, 26, but more fully and better, *Proposition* 5, 6, 7, *Pag.* 92, 95, 96, by which you make two Tables, one of Horizontal spaces, the other of Altitudes. So that I shall not need to say any more of it. By that work (I say) you may make two Tables which may serve to prick down the houre points, which points you shall see to winde about the center in forme of an Ellipsis.

1. It is first requisite that the proper Meridian of the plain be rightly situated upon the plain (as is there also expressely required. And it is again requisite that the proper line of the two sixes (proper I mean to the plain, considered as an Horizon by it selfe) be also drawn: which line (as in all Horizontal Dials is usuall) must be perpendicular (upon the plain) to the proper Meridian. And the points also of the

two ſixes muſt be carefully ſet on, whoſe diſtance from the center is the longer Radius of the Ellipſis. The reaſon why theſe points of the proper Sines muſt be had, is, becauſe the new Ellipſis (which we now look for) muſt paſſe through them both. So alſo the juſt point of the proper 12 (or the ſection of the Ellipſis with the plains proper Meridian) muſt be with the ſame care deſigned upon the plain. And the Subindicall line muſt be drawn in its true poſition upon the plain, according to the proper declination of the Index.

2. After this is done, you muſt call to minde what the Declination and Reclination of your Index is (I ſpeak now of the proper Declination and Reclination before mentioned) as *Pag.* 172 is mentioned.

3. Then from every houre point lately made upon the plain, you are to draw right lines, parallel to the ſubindicall line, and draw them both wayes or on both ſides of each houre point, becauſe you know not which of them (as yet) you are to make uſe of for the pricking down of your New or Diſtorted Ellipſis.

4. Take the larger Radius of your primary Ellipſis (that is the length from the center of it, to the point of the proper ſix a clock) and (upon the Sector, for that Inſtrument is moſt fit for this uſe or practiſe) entering it upon the Tangent of 45 degrees, open your Sector to that length: then take over from the reclination of the Index (the proper reclination I now ſpeak of) counted on the ſame Scale of Tangents, to the other leg, and reſerve this length. That is, As the Radius, to the Tangent of the proper reclination of the Index; So is the larger Semidiameter of the primary Ellipſis, to a fourth quantity, which is equall to the former reſerved length, and to that large Semidiameter or Radius, is the Tangent of the Indexes proper Reclination.

5. This

5. This reſerved length muſt again be entered from 90 in the line of Sines, and the Sector ſet according to it, and being ſo ſet it is fit for the reſt of the work that is to enſue. Becauſe this proportion we are to go upon: As the Radius, to the Tangent of the Indexes proper reclination (which two terms are they that now do ſet the Sector,) ſo is the Sine of every altitude of the horary points in the Equinoctiall, (which altitudes your Table of altitudes computed by the forementioned Propoſition, *Pag. 96, 97,* will help you unto,) ſo is the Sine of every (horary-equinoctiall-points) altitude, to the Tangent of the reclination of every one of thoſe ſeverall houre points of the Equinoctiall Circle. Note that the reclinations here mentioned are, in reſpect, and from the proper Zenith line of the plain. And note alſo that theſe Tangents thus found, are to be eſtimated to the larger ſemidiameter of the primary Ellipſis as to their proper Radius.

6. By theſe Tangents ſo found, you are to ſet on the new houre points, by which both the new Ellipſis is to be deſcribed and alſo divided. I ſay the new houre points are to be ſet on upon the lines drawn through each of the old houre-points parallel to the Subindicall line, and they are to be ſet on from each of the ſaid old houre points in thoſe lines. But which way, or on which ſide of them, will be ſtill doubted; as was before mentioned § 3. And to take away this doubt, it will be beſt to conſider the point of the proper 12 upon the primary Ellipſis, when the Sun is (any day) in that proper 12 point of the heavens, then muſt the upright (or proper Index of the plain) caſt its ſhadow into the proper 12 point of the primary Ellipſis. Then further, ſuppoſing the Sun to ſtand ſtill there, imagine how your ſlope Index is to lie from the proper Index, and by that you ſhall eaſily diſcern which way the inclination of that Index will wry the

proper point of 12 from the primary Ellipſis, and conſequently you ſhall be able (thereby) to judge upon which part of that line which is drawn rhrough the point of proper 12 (parallel to the ſubindicall line) the houre (of proper 12) ſhall be caſt into the ſecondary Ellipſis from the primary. This point being ſet right, you may place all the houre points from that proper 12 to the two proper fixes, the ſame way with this firſt point: but all the other points on the remoter ſide of the proper 12, muſt go the contrary way, as you will eaſily perceive, the very figure of the Ellipſis will require it ſhould ſo be.

As here. R S is the Subindical line, over which the Index leaneth.

O the point of proper 12 upon P O Q the primary Ellipſis.

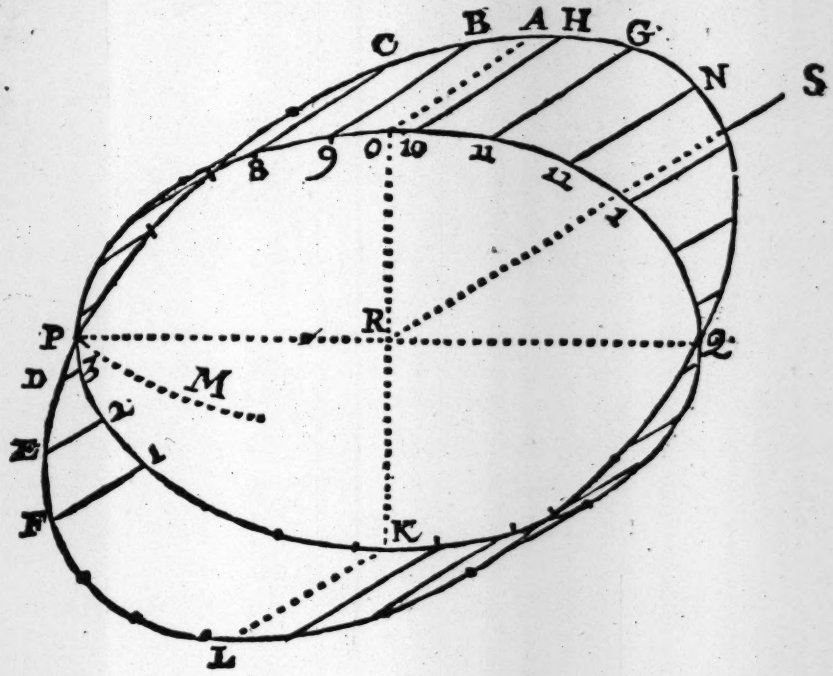
O A, 9 B, 8 C, &c. parallel lines through the houre points in the primary Ellipſis, parallel I ſay to the Subindicall line R S.

P Q the two proper fixes, through which alwayes the diſtorted Ellipſis muſt paſſe.

Then becauſe the Index leaneth from the upright Index (or Zenith line of the plain) towards S, therefore the proper 12 at O muſt go towards S, *viz.* to A: and therefore alſo 9 B, 8 C, &c. 11 G, &c. muſt go the ſame way till you come to the two proper fixes at P and Q, and then the houre points D E F muſt be ſet from 3 2 1, the contrary way to that wherein the firſt houres were placed; as you may plainly ſee the form of the new Ellipſis will require. For it cannot poſſibly be made to turn again from P towards M, if it muſt make up an Ellipſis, as in this caſe it is neceſſary it ſhould do.

Now all the Tangents before found (§ 5) are the lines

10 H,



10 H, 9 B, 8 C, 11 G, &c. each ſet off from his proper houre point at O, A, B, C, and taken to its true Radius, namely, the Radius P R or R Q. But if you work by the Sector (as is taught in the 5 §) the very lengths there found ſhall be the quantities here to be ſet off, namely, 10 H, 9 B, 8 C, 11 G, 12 N, &c. without any more relation to the Radius P R, without any more relation (I ſay) than what was formerly done upon the work of the Sector § 5. The like may be done for halves and quarters of houres. And ſo theſe directions will be enough for pricking down the houre points this way.

Another way followeth.

A second way to make the Ellipsis and houres to a slope Index upon a plain: and without trouble of making that Table before mentioned.

THis way will be more expedite than the former. I shall here suppose these particulars to be again done by the former precepts.

1. That the plains proper Meridian R O, is rightly placed.

2. That P R Q is drawn perpendicular thereunto.

3. That the Subindicall line R S is also rightly placed from R O the proper Meridian.

4. That R P or R Q being determined for the Radius, R O and R K are each of them the Sines of the plains propet Latitude.

5. From the points O and K (which are the two proper points of 12 to an Index standing perpendicularly to the plain) let O A and K L be drawn parallel to R S the Subindicall line.

6. Then to the Radius R P, finde the Sine of the plains difference of Longitude from your Meridian [because I purpose here to shew how to work all from your 12 a clock line, though there is no obligation to that houre, but all may be done just in the same manner from any other houre point, if you account the plains difference of Longitude from some one of them, which is easie to do: as if in this Example the dif-

difference of Longitude from 12 be 36 *gr.* then from 11 it muſt be 21 *gr.* from 10 it muſt be 6 *gr.* from 1 a clock it muſt be 51 *gr.* &c. to all or any of the other houres] which here for example ſake we will ſay to be 36 *gr.* With that Sine ſet off R T, and draw T I parallel to R O the proper Meridian. Then again to the Radius R O, finde out the Co-ſine of the difference of Longitude, and ſet it upon the line T I, from T to I. All this work is only to finde the point of 12 in the primary Ellipſis, as you ſee it expreſſed in the former Figure at 12. The like work you muſt do to finde the point of one of the houres of ſix in the primary Ellipſis, becauſe ſix is 90 *gr.* from 12. [If you had choſen the point of 11 to work by, you muſt have lookt for the point of 5 a clock, becauſe that point is the 90th *gr.* from 11, if 10, then 4, &c.] That is, to the Radius R O finde the Sine of the difference of Longitude, and ſet it from R to V, and then draw V X parallel to P R the line of the plains proper ſix. Then to the Radius R P finde the Co-ſine of the ſaid difference of Longitude. and ſet it upon V X from V to X: So ſhall X be the point of your own ſix a clock upon the proper Ellipſis; as you may ſee in the Figure is expreſſed.

Now through theſe two points I and X draw right lines parallel to the Subindical line R S.

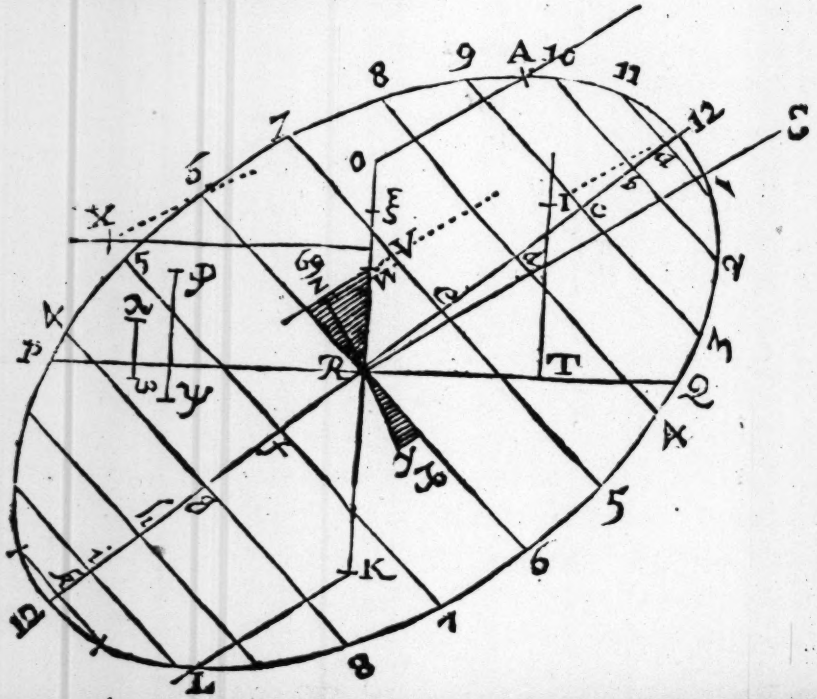
Then knowing the Altitudes of your 12 and 6 hours (by this *Lemma*) finde the Sines of them to the Radius P R. Afterwards ſay, As the Radius, to the Tangent of the co-

If this way of finding the two points I and X, ſeeme not ſo expedite, you muſt remember that all the work here is done without the two forementioned calculated Tables.

LEMMA.

How to finde the altitudes of your 12 *and* 6 *houre points (in the Equinoctiall) above your Diall plain. As the Radius is to the Sine of the Equi-*

Equinoctiall altitude above the plain; ſo is the co-ſine of the difference of longitude, to the ſine of the altitude of 12. And ſo is the ſine of the difference of longitude: to the altitude of ſix above the plain. If you uſe other houres then 12 and 6, yet you muſt work in the ſame manner ſtill, with the complement of the difference of longitude, and the difference of Longitude it ſelf, and ſo finde two conjugate Diameters in the ſelf ſame manner. reclination of the Index; ſo theſe two Sines now found, to two other lengths. Theſe lengths ſet upon the parallel lines lately drawn, each to his proper houre, namely from 1 to 12, & from X to 6: ſo have you found the two points of 12 and 6 in your new diſtorted Ellipſis that is to be deſcribed. And drawing R 12, and R 6, you ſhall have two conjugate Diameters, 12 *R* 12, and 6 *R* 6; and then the reſt of the work will be eaſie.



For

For if you divide R 12 (both wayes) as a line of Sines (R *e* and R *f* being Sines of 15 *gr.* R *d* and R *g* Sines of 30 *gr.* &c. R 12 and R 12 Sines of 90 *gr.*) at *a*, *b*, *c*, *d*, *e*, R, *f*, *g*, *h*, *i*, *k*; you must then draw right lines through each of those points (each one parallel to the conjugate diameter 6 R 6.) And when that is done, make R 6 a Radius, and to that Radius make *e* 7, *e* 5, *f* 5, *f* 7, to be the Sine of 75 *gr.* or one houre under 90. Make *d* 8, *d* 4, *g* 4, *g* 8, the Sine of 60 *gr.* or two houres lesse than 90. So *c* 9, *c* 3, is the Sine of three houres under 90: *b* 10, *b* 2, of four houres under 90: *a* 11, *a* 1, is the Sine of five houres under 90, or of one houre. The like you may do for halves and quarters, or what other parts you desire.

Thus much likewise for this second way.

Alwayes you must remember to put all things upon their right Coasts.

Concerning the Zodiac, *how it is to be limited and placed.*

TO omit other wayes, I shall here pitch upon that which is most suitable to this manner of working upon which we now are. To the Radius P R (which is the larger Semidiameter of the primary Ellipsis) first, finde the Tangent of 23 degrees and a halfe; which suppose to be R ξ: and then to this line, being taken as a new Radius, finde the Co-sine of the plains Latitude, or the Sine of the Equinoctials altitude, which suppose to be the length R W, which is also to be set from the center R upon the proper Meridian of the plain, as here it is from R to W. Then through the point W, draw a line, as W Z, parallel to the subindical line R S.

When this is done you are to finde the Sine of the Poles elevation above the plain, to the ſame Radius R ξ, which Sine you may ſuppoſe to be the length of the line φ ↓. Then ſay again; As the Radius, to the Tangent of the Indexes reclination; ſo φ ↓ (the Sine of the Poles elevation above the plain) to a fourth line; which line let be repreſented by λ ω. Take this line λ ω therefore, and ſet it upon W Z, the line formerly drawn, from W to Z. And laſtly, draw the line R Z, and make R ɣ equall to it, ſo ſhall Z ɣ be the Zodiac in its true length and poſition: and R Z or R ɣ ſhall give the halfe of it, which halfe is to be eſtimated as a Tangent of 23 degrees and a halfe, and ſo the Zodiac to be ſet on as hath formerly been often ſhewed.

You are here to take care that all things be ſet in their right poſition. In this example, Z turns from W towards the left hand, becauſe it is here ſuppoſed that the North Pole is elevated upon the plain, and ſo the Axis riſeth out of R above the plain: and therefore that 23½ tangent degree upon that Axis are above the plain. From which extream point of 23½ above the plain, you may ſuppoſe a line to iſſue out parallel to the Index, which inclines from R towards S, and therefore that line inclining ſo too, muſt project that extream point from W towards Z. All the reaſon of the work depends upon that which hath been formerly ſaid: Namely, that both houre points of the Equinoctiall, and declination points in the Axis, are all projected from their true poſitions in the Sphere (upon or unto a plain) by right lines paſſing through each of them, parallel to the aſſigned Index. I ſhall need to ſay no more, becauſe I think enough (if not too much) hath been ſaid already.

This ſhall ſerve for the Effection and Demonſtration alſo of this Propoſition or Probleme.

C o-

CORONIDIS LOCO:

I shall here further adde;

How upon an Horizontal Plain, to describe an Elliptical Diall to an Index lying aslope, and pointing into some assigned Longitude and Latitude.

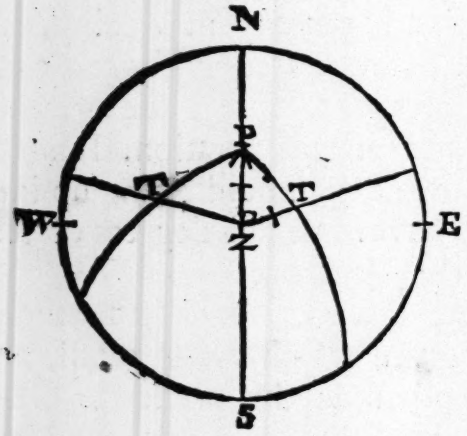
THis I shall adde as a *Corollary* to that which hath last of all been delivered in general for all Plains and Indexes. Out of which Doctrine this (as a particular branch) is deduced. It containeth not any new thing, but because it may be more frequently made use of (in practise) than other Cases, therefore I adde it, that it may also be the more plain and easie in operation. It is (for more ease) intended that the Index should point up into some just houre Circle, and to have some just degrees of Reclination from the Zenith of the Horizon.

I purpose not to give variety of wayes, for they are shewed in the last precepts now given which are generall, and may easily be brought and applyed to this particular Case, as a branch of that generall before.

Suppose in our Horizon 51 *gr.* 30 *min.* in Latitude, and to two Indexes set upon an Horizontall plain, the one pointing South-east into the morning Circle of 7 a clock, the other pointing South-west into the evening Circle of 5 a clock, and each of them reclining 45 *gr.* it were required to make two Ellipticall Dials: How must they be done?

It must be noted that the making of one will make the other, because they are to be set upon one plain, and their differences of the Indexes Longitudes, is in each 5 houres, and the reclination of the Index in each 45 degrees. Only the Coasts in respect of situation must be changed, because the positions of the Indexes are not parallel, but contrary one to the other, and so will the Ellipses be, as you may see in the next page. The first thing to be done, is,

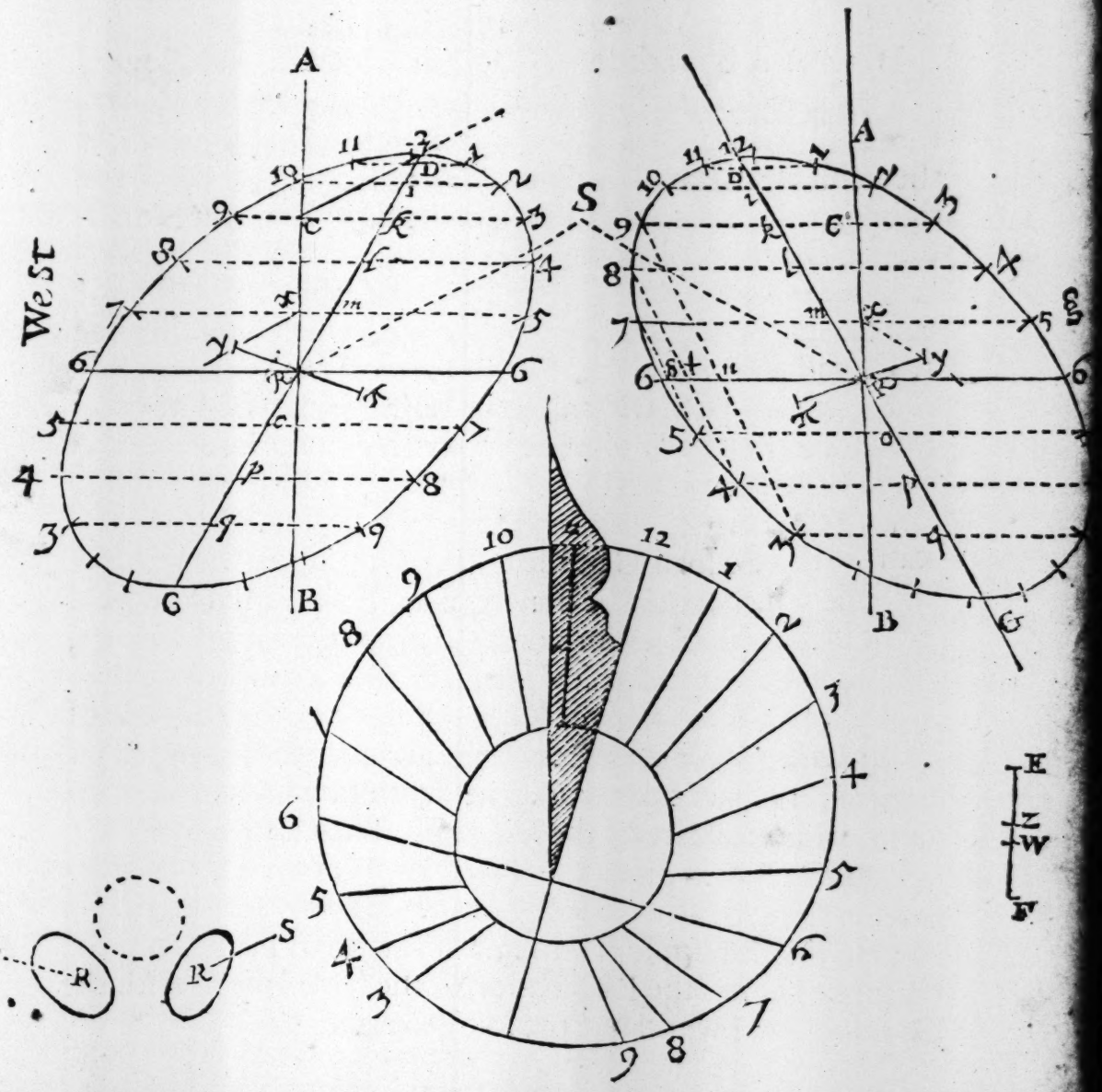
By having the difference of the Indexes Longitude (75 *gr.*) and the reclinarion of the Index (45 *gr.*) to finde what declination the Index must have: Or to finde the declination of the subindicall line from our Meridian.



For solution you must resolve the Sphericall Triangle P Z T, wherein P Z is 38 *gr.* 30 *min.* Z T is 45 *gr.* Z P T is 75 *gr.* all these are given: by these you may finde the declination now required, (for we suppose the Index to point up into T) which is P Z T, North-east, or North-west. And in

NORTH

If these two Ellipses in this position should be inconvenient, in regard the two Indexes may possibly interfeer, you may change their places, and then the two Indexes will look one from the other. And then also the Horizontall Diall will best stand on this side of them; for they will lie most open on this side, thus:



Instead of this Horizontal Diall you may place the Circular Dial, *pag.* 120.

in this case P Z T will be 60 *gr.* 5 *min.* P T will be 39 *gr.* 23 *min.* So that the Latitude of the Index will be 50 *gr.* 37 *min.*

When this work is done;

Draw A R B for the Meridian line of North and South, and 6 R 6 for the line of East and West, crossing each other at R, which must be the center of the Diall, and draw the Subindicall line R S 60 *gr.* 5 *min.* from A R upon the right Coast, that is, North-east in the first plain, and North-west in the other plain.

Then making 6 R for Radius, finde thereto the Sine of the Latitude of the place 51 *gr.* 30 *min.* which let be the line R C, and set it upon the North part of the Meridian line A B (I call it the Meridian line because it is the said line upon the Horizontal plain whereupon these descriptions are now made) from the center R to C. Then from the point C, draw C D parallel, and the same way with R S the Subindicall line. So shall C be the point of 12 upon the primary Ellipsis which should be drawn, if an Ellipticall Diall were to be made upon the Horizontall plain to the upright Index, which is the proper Zenith line of the Horizontall plain.

After this, to the same Radius R 6, finde the Co-sine of your Latitude, or the Sine of the Equinoctials height, or rather (in this particular work) the depth of it under the Horizon, which Sine let be the line E F. Then say,

As the Radius, is to the Tangent of 45 *gr.* the Indexes reclination; so is the Sine E F, to a fourth; which fourth will be (in this Example) the same line with E F, because the Tangent of 45 (the Reclination) is the same length with the Radius, yet I will call it the fourth quantity.

Take this fourth quantity and set it off upon the line C D, from C to D, so shall D give the point of 12 upon the

distorte

distorted Ellipsis, which is the 12 that fitteth with the reclining Index with which we have now to deal. Then draw (from R to D) the line R D, both wayes, as D R G is done.

By these meanes we have now got two conjugate Diameters. And now the rest of the work will be easie. For you are onely to

Divide the Semidiameters R D and R G (from R towards the extremities) each of them as a line of Sines. That is, R *m*, R *o*, make the Sine of 1 hour or 15 *gr.* So R *l*, R *p*, the Sine of 30, or 2 hours: R *k*, R *q*, the Sine of 45 *gr.* or 3 houres: R *i* the Sine of 60 *gr.* or 4 hours: R *h* the Sine of 5 houres: R D or R 12, the whole Sine or Sine of 90 *gr.*

Then through each of these points at *h*, *i*, *k*, *l*, *m*, R, *o*, *p*, *q*, draw a line parallel to the other conjugate Diameter, namely, to 6 R 6.

This done, make *R* 6 a Radius, and to that Radius make *m* 7, *m* 5, *o* 7, *o* 5 (each of them) a Sine of 5 hours or 75 degrees. Make *l* 8, *l* 4, *p* 4, *p* 8, a Sine of 4 hours or 60 *gr.* Make *k* 9, *k* 3, *q* 3, *q* 9, (each of them) a Sine of 3 houres or 45 *gr.* So *i* 10, *i* 2, must be the Sine of 2 houres: and *h* 11, *h* 1, the Sine of 1 houre or 15 *gr.* By this work you shall (upon the former parallel lines drawn through *h*, *i*, *k*, *l*, *m*, *o*, *p*, *q*,) finde the houre points of 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 1, 2, 3, 4, 5, 6, 7, 8, 9. In which you are to signe out the houre points, and through which you are to draw the Ellipsis, as you see the figure for a pattern.

You might also have divided each of the Radiusses, noted with *R* 6 into parts correspondent to a line of Sines, as you see partly done at the letters *s t u*, in the last of the two former Schemes) as at *s t u* is expressed, and through those points you must draw paralle's to the other Diameter

D R G.

in this caſe P Z T will be 60 *gr.* 5 *min.* P T will be 39 *gr.* 23 *min.* So that the Latitude of the Index will be 50 *gr.* 37 *min.*

When this work is done;

Draw A R B for the Meridian line of North and South, and 6 R 6 for the line of Eaſt and Weſt, croſſing each other at R, which muſt be the center of the Diall, and draw the Subindicall line R S 60 *gr.* 5 *min.* from A R upon the right Coaſt, that is, North-eaſt in the firſt plain, and North-weſt in the other plain.

Then making 6 R for Radius, finde thereto the Sine of the Latitude of the place 51 *gr.* 30 *min.* which let be the line, R C, and ſet it upon the North part of the Meridian line A B (I call it the Meridian line becauſe it is the ſaid line upon the Horizontal plain whereupon theſe deſcriptions are now made) from the center R to C. Then from the point C, draw C D parallel, and the ſame way with R S the Subindicall line. So ſhall C be the point of 12 upon the primary Ellipſis which ſhould be drawn, if an Ellipticall Diall were to be made upon the Horizontall plain to the upright Index, which is the proper Zenith line of the Horizontall plain.

After this, to the ſame Radius R 6, finde the Co-ſine of your Latitude, or the Sine of the Equinoctials height, or rather (in this particular work) the depth of it under the Horizon, which Sine let be the line E F. Then ſay,

As the Radius, is to the Tangent of 45 *gr.* the Indexes reclination; ſo is the Sine E F, to a fourth; which fourth will be (in this Example) the ſame line with E F, becauſe the Tangent of 45 (the Reclination) is the ſame length with the Radius, yet I will call it the fourth quantity.

Take this fourth quantity and ſet it off upon the line C D, from C to D, ſo ſhall D give the point of 12 upon the

diſtance

distorted Ellipsis, which is the 12 that fitteth with the reclining Index with which we have now to deal. Then draw (from R to D) the line R D, both wayes, as D R G is done.

By these meanes we have now got two conjugate Diameters. And now the rest of the work will be easie. For you are onely to

Divide the Semidiameters R D and R G (from R towards the extremities) each of them as a line of Sines. That is, R *m*, R *o*, make the Sine of 1 hour or 15 *gr.* So R *l*, R *p*, the Sine of 30, or 2 hours: R *k*, R *q*, the Sine of 45 *gr.* or 3 houres: R *i* the Sine of 60 *gr.* or 4 hours: R *h* the Sine of 5 houres: R D or R 12, the whole Sine or Sine of 90 *gr.*

Then through each of these points at *h*, *i*, *k*, *l*, *m*, R, *o*, *p*, *q*, draw a line parallel to the other conjugate Diameter, namely, to 6 R 6.

This done, make *R* 6 a Radius, and to that Radius make *m* 7, *m* 5, *o* 7, *o* 5 (each of them) a Sine of 5 hours or 75 degrees. Make *l* 8, *l* 4, *p* 4, *p* 8, a Sine of 4 hours or 60 *gr.* Make *k* 9, *k* 3, *q* 3, *q* 9, (each of them) a Sine of 3 houres or 45 *gr.* So *i* 10, *i* 2, must be the Sine of 2 houres: and *h* 11, *h* 1, the Sine of 1 houre or 15 *gr.* By this work you shall (upon the former parallel lines drawn through *h*, *i*, *k*, *l*, *m*, *o*, *p*, *q*,) finde the houre points of 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 1, 2, 3, 4, 5, 6, 7, 8, 9; In which you are to signe out the houre points, and through which you are to draw the Ellipsis, as you see the figure for a pattern.

You might also have divided each of the Radiusses, noted with *R* 6 into parts correspondent to a line of Sines, as you see partly done at the letters *s t u*, in the last of the two former Schemes) as at *s t u* is expressed, and through those points you must draw parallels to the other Diameter

D R G.

D R G. Then to the Radius D R make *s* 7, *s* 5, the Sine of 15 *gr.* or 1 hour: *t* 8, *t* 4, the Sine of 30 *gr.* or two hours: *u* 9, *u* 3, the Sine of 45 *gr.* or 3 houres; and so forward: by which work you shall finde the same houre points (3, 4, 5, 6, 7, 8, 9, &c.) that you did before, and so you may finde out and draw the Ellipsis by them.

The same manner of work is to be performed for halves and quarters of the severall houres.

How the Zodiac is to be placed and limited.

IT is the same work with that which went before, *Pag.* 185. yet I will here insert it again.

First, work thus. As the Radius, is to the Tangent of 23½ *gr.* So let E F (which was formerly found to be the Sine of the Equinoctials altitude above the Horizon 38 *gr.* 30 *mn.* in respect of the Radius R 6, and must now again be here used) be to a fourth quantity, which suppose to be F W. Take therefore that length F W, and set it from R to X on the North side (in this example:) and through X draw X *y* parallel to the Subindicall line R S.

Then say again. As the Radius, is to the Tangent of 23 *gr.* and an half; So let R C (which was before found to be the Sine of the Latitude of the place 51 *gr.* and an half in respect of the Radius R 6, and comes now to be here used again) be to a fourth quantity, which suppose to be F *z*. Take therefore F *z*, and set it upon the line formerly drawn through X, from X, contrary to the going of the Subindical line, namely Southward (in this example) I say from X to *y*, Then from *y* through R, draw *y* R *π*, and make R *π* equall to R *y*, So shall *y π* be the Zodiac both placed rightly and justly limited.

For

For diviſion of it, you muſt conceive that R ♈ or R ♓ is a Tangent of 23 and an half *gr.* the Suns greateſt declination, and conſequently you may by it ſet on either 12 moneths, or 12 ſignes, as you will; the manner whereof hath been often ſhewed in this Book, and eſpecially *Pag.* 10, 11. and *Pag.* 14, 15, &c. ſo that now all this work is come to an end. The Index muſt ſlide to and fro upon the line ♈ ♓ (or the Index ſtanding, the Ellipſis muſt move after the ſame rate) ♈ ♓ is the proper Meridian of the Index. And if your work (when you make this Diall, according to this caſe here before put) be exactly true, you ſhall finde the Zodiacall line ♓ ♈ to fall juſt into the houre lines of 5 and 7, as they ought to do, becauſe the difference of the Indexes Longitude was aſſumed to be 75 *gr.* from the South Meridian of the place, which is the ſame with thoſe houres.

The ſigne ♋ muſt be placed at ♈, and ♑ at ♓ in this Diall.

The Index muſt lie (when it is in the Center R) juſt over the line R S, and muſt alwayes move in a parallel poſition to it ſelf. And it muſt in this example recline 45 *gr.* or riſe above the Horizon (or above R S making an angle above that line 45 *gr.* alſo. But though it lie thus, yet it muſt move in the line ♈ ♓, and it muſt be ſo ſet on, that when you project the fiduciall edge of it into a point (as workmen uſe to do, when with their eye they trie the ſtraightneſſe of a line) all that edge may at once juſtly appear to run into the line ♈ ♓, wherever the Index be ſet in the Zodiac. This is to be done carefully.

I have here ſet two of them, whoſe proper Meridians, (I mean proper to the Index, which are the lines of their Zodiacs, *viz.* ♈ ♓) do not lie in one and the ſame right line, or parallelilm (which is the ſameneſſe of poſition) but make angles one to the other. This is done, becauſe they ſhould

not lie in one Meridian: for by that meanes they will alwayes ſet one another, which the Horizontal Diall with the ſingle Ellipſis to an upright Index will not do at all times. Theſe two, I ſay, will ſet themſelves: and if you adde a common Horizontall Diall more, to ſtand between them, as you ſee done there, they will be the more ſpecious and uſefull for ſetting each other.

I have ſet that whoſe Index looks North-eaſt upon the left hand, you may ſet it on the right hand if you will, and the other on the left. For this makes no materiall change.

The Index is beſt to be a threed. Other circumſtances I remember none but what the Workman will be well able to go through.

Another

Another way for the description of an Elliptical Diall upon the Horizontall plain of 51 gr. 30 min. *Latitude, whose Zodiac, and the motion of the Index is performed upon the houres of* 7 *in the morning, and of* 5 *in the afternoon, as the same houres are drawn upon the common Horizontall Diall.*

THis way was formerly written, and though it need not to have been here placed, in respect the way last given is the best, yet because it doth somwhat differ from what was set down before, I thought best not to omit it: because it is delightfull to see different wayes meet both in one effect.

1. First, you are to get (this way) the altitudes of each houre point in the Equinoctiall, above the Horizon, by this Rule.

As the Radius, to the Sine of 38 *gr.* 30 *min.*
So the Sines of 75, 60, 45, 30, 15 *gr.* to so many 4th Sines.

The Co-ſines of theſe will limit out the points (upon the houres of the Horizontall Diall formerly drawn) through which the Ellipſis upon the Horizontall plain (made for an upright Index) is to paſſe: as is ſhewed before in the 28, 29, 30, and 31, *Pages*, which points in the figure of the next *Page* may be repreſented by 8, 9, 10, 11, 12, 1, 2, 3, &c.

2. As the Radius, to the Tangent of the reclination of the Index;
So are the 4th Sines before found, to ſo many 7th terms.

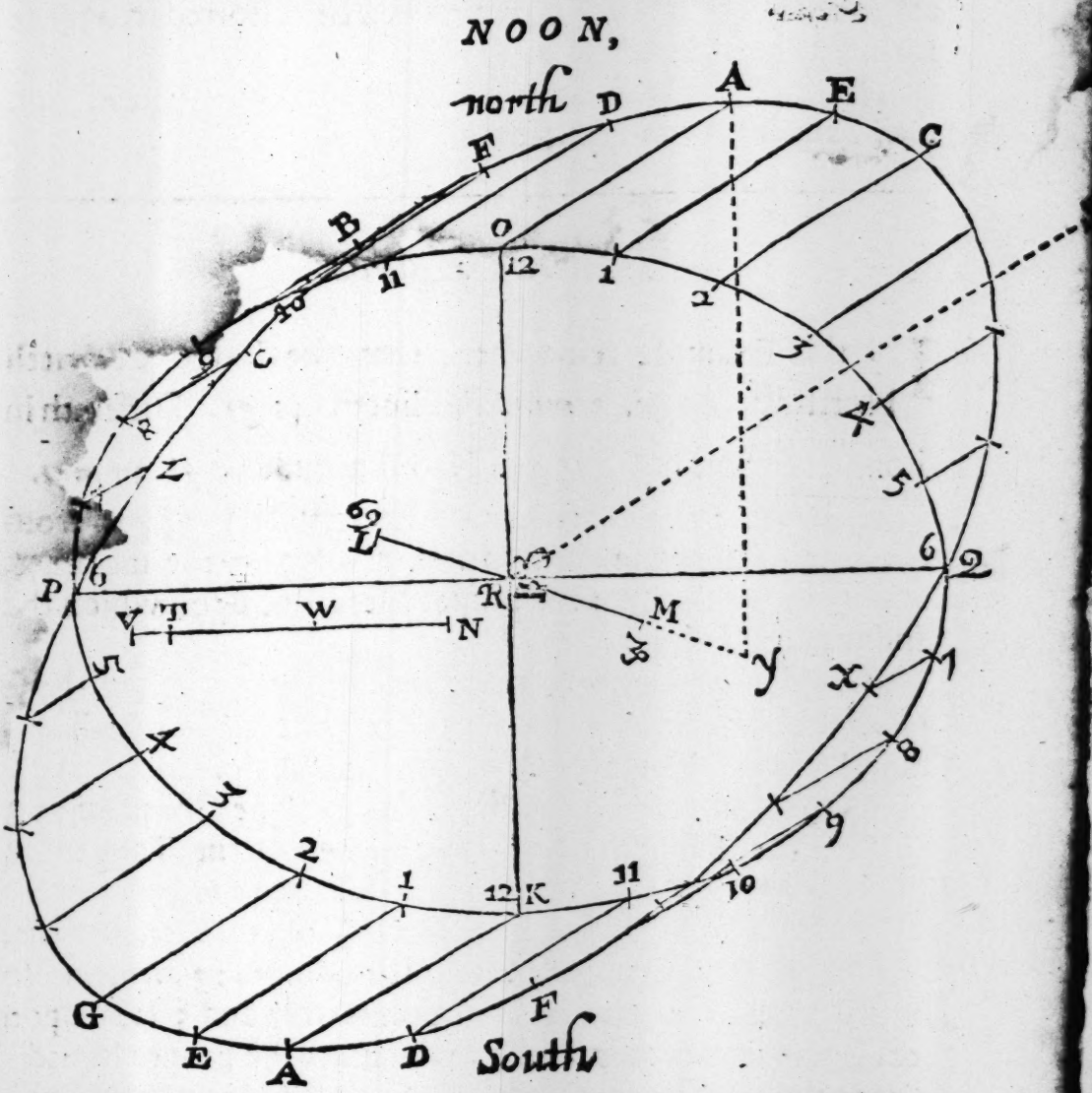
3. Deſcribe the regular Horizontall Ellipſis, as you ſee P O Q: which you muſt know to be for the Latitude of 51 *gr.* 30 *min.* and that P Q are the points of the two ſixes, and O K the points of the two twelves, *viz.* at Noon and Midnight: and alſo that all the houres are regularly ſet down to O P Q K, &c.

Suppoſe here an Index to	*gr.*	*m.*
Recline Northwards	45	00
Differ in Longit. S^{E}_{W}	75	00
Conſequently it muſt		
Decline North $^{East}_{Weſt}$	60	05
Have North Latitude	50	37

4. From each point there ſet down, draw lines parallel to the Subindicall line R S, as O A, 8 C, 9 B, &c. the angle O R S muſt be 60 *gr.* 5 *min.*

5. Upon theſe lines, and from the foreſaid Ellipticall points (Northward frō the ſixes towards the North, Southward from the hours on the South ſide of the two ſixes) ſet on the reſpective 7th terms: the firſt upon the line drawn from the point of 12, from O to A: the ſecond (proceeding from 75 in the former work) ſet from 11 and 1, to D and E: the third of thoſe

thoſe 7th terms (proceeding from 60 in the former work) ſet from 10 and 2, to F and G, And ſo all the reſt in their orders. Thoſe from the two ſixes toward 12 at Noon, muſt be ſet Northward from the points 9, 10, 11, 12, &c. And thoſe from the two ſixes towards 12 at night (which in the



Diall

Diall ſtands toward the South) muſt be ſet Southwards, in this example where the reclination of the Index is toward the North: But if the reclination had been towards the South, it ſhould then be quite contrary.

6. Through theſe new points **B F D A E G**, &c. you are to draw a new Ellipſis, which will be diſtorted from the former Ellipſis firſt drawn.

Thus the Diall it ſelfe for the houre points is limited, you may adde halves and quarters.

For the Zodiac.

IN this Example remember, that the Index declineth North $\frac{\text{East}}{\text{Weſt}}$ 60 *gr.* 5 *min.* Reclineth 45 *gr.* Differeth in Longitude South $\frac{\text{East}}{\text{Weſt}}$ 75 *gr.* Hath Latitude 50 *gr.* 37 *min.*

1. Becauſe the difference of Longitude is 75 *gr.* from the South, therefore our two houres of 7 in the morning, and 5 at evening, are the proper Meridians upon which the Indexes muſt ſlide.

2. For that cauſe you muſt conſider how much of thoſe two Meridians is intercepted between the Equinoctiall and our Horizon. You may findeit by this Rule.

As the Radius, is to the Sine of 15 *gr.* (the Conpl. of 75,)
So is the Tangent of 38 *gr.* 30 *min.* to the Tangent of
11 *gr.* 38 *min.* which is the arke required.

3. Becauſe the Latitude of the Index is 50 *gr.* 37 *min.* North, the complement of it muſt be 39 *gr.* 23 *min.* and ſo much under the Equinoctiall points of 7 and 5 (and upon the houre circles of 7 and 5, which are the proper Meridians to the two Indexes) doth the proper Horizon of each

of

of those Indexes cut the said houres of 7 and 5 upon the South-east and South-west; and so much do they cut the same Meridians above the Equinoctiall upon the South-west and South-east. So that upon the Southerly Coast, that portion of these Meridians which is comprehended between the Equinoctiall and our Horizon, namely 11 *gr.* 38 *min.* must be taken from 39 *gr.* 23 *min.* and the remainder will be 27 *gr.* 45 *min.* which is the arke comprehended between the proper Horizon of the Index and our own Horizon, which upon the South part (in this particular Example) is below our Horizon, on the North part above.

4. First, therefore the limitation of the Semi-Zodiacs length must be so that Latitude of the Index or proper Horizon 50 *gr.* 37 *min.* And then secondly, the said Zodiac first found and limited must be augmented (in this Example) in proportion of the Radius to the Secant of 27 *gr.* 45 *min.* In this manner, by the second rule given at the beginning of this Book *Pag.* 11. To the Radius P R finde the Cosine of the Latitude of the Index, namely the Sine of 39 *gr.* 23 *min.* which suppose to be N T.

To this length N T as a Radius, finde out the Secant of the forementioned arke 27 *gr.* 45 *min.* which suppose to be N V.

This length N V shall give the Radius or Tangent of 45 *gr.* which is the Tangent or Decimall Scale, out of which (either of them) you are to make your Zodiac by the numbers of those Tables in the 6 and 7 *Pages.*

To this Radius or Decimall Scale, or Tangent of 45 *gr.* N W is the Tangent of 23 *gr.* and a halfe, wherefore the Semizodiac, R L or R M is to be made equall in length to N W. Thus the Zodiacs length is limited.

For the position of the Zodiac, it was before said, that it must

must lie in the line of 7 in the morning, or 5 in the afternoon. So in this last figure you see it points to Z, which is 7 in the morning, (and consequently also to X, which is 7 in the evening) in the distorted Ellipsis: because this is that Diall whose Index looks North-east: you see it do so likewise in the first figure *Pag.* 189, as in the second figure there it lies to 5 in the evening, and consequently also to 5 in the morning.

Observe in the last figure (which is as true and just in the two other *Pag.* 189.) that the angle P R Z, and so Q R X, is equall to the angle made (upon our common Horizontall Diall) between 6 and 7 a clock, namely, 18 *gr.* 54 *min.* and consequently that 1 R 1 (a line drawn from 1 to 1 in the primary Ellipsis) is perpendicular to the Zodiac L M: but P R C is not equall to the angle thereon between 6 and ♂ a clock; nor is it so in any other of the houres.

Observe again, that if a line be drawn parallel to O K, through A the point of 12 in the distorted Ellipsis, till it meet with the Zodiac (extended) at ♈; observe (I say) that if R M be taken as a Tangent of 23½ *gr.* (as it is taken in this work) then will R ♈ be the Tangent of (the complement of your Latitude, namely) 38 *gr.* 30 *min.* And this must be so, because if the Sun should decline 38 *gr.* 30 *min.* Southward, then the Sun must only peep up upon the Horizon at 12, and consequently the shadow of the Index (namely the point of it that intersects with your Horizon, for the Sun hath no altitude at that place and time) must run full from South to North to shew the point of 12 at A.

Other observations might be made, but I go no further.

The reason of the precedent work will be demonstrated out of the former things delivered in this Book: especially out of this last Treatise, which begins *Pag.* 171, and ends *Pag.* 186.

Pag. 186. And therefore I wholly omit to adde any thing more to this particular ſubject.

They that underſtand the things before, will not be to ſeeke in the neceſſary Demonſtrations of theſe particulars.

A Note concerning the framing of Dials to finde the Azimuth.

AS the Axis of the world is to the Equinoctial Circle, ſo is the Zenith line to the Horizon of any place.

Whence it will follow: That whatſoever is in this Book declared concerning the projection of the houre points of the Equinoctiall Circle upon any plain, &c. the ſame may be applied to the projection of Azimuths or points of the Horizon upon any plain, &c. Onely *mutatis mutandis*, *(i.e.)* inſtead of the Equinoctiall and Poles of the World, you are to uſe the Horizon and the Poles of it, *(i.e.)* Zenith and Nadir.

Then for the Zodiac (which depends upon the Scale or Tangents of Declination, which exceed not 23 and a half *gr.* you are to uſe (in the Azimuthal work) a Scale of Tangents (rightly limited) going up from 00 to ſo much altitude as you mean to uſe (if it be for the Suns courſe, to 62 *gr.* here at *London.*)

As there you rectifie the Index to the Declination of the Sun: So here you muſt (anſwerably) rectifie it to the Suns altitude taken by obſervation, and then the Index being ſet

to the altitude gives the Azimuth for that moment and no more.

COROLLARY.

Therefore, *to finde the Azimuth by this way, you muſt take the Suns Altitude, and ſo finde the Azimuth for one moment onely.*

Queſt. But why is there ſo little ſaid here of this?

Anſw. Becauſe it is a thing of no uſe, but of a great deal of trouble: for the altitude is to be obſerved, and the Index ſet thereto every moment,

Queſt. Is it not ſo too in the Dials before deſcribed?

Anſw. No; for there the Index ſet once, may ſerve in that place one whole day very well, becauſe the Suns declination doth not alter much in one day.

Queſt. Why then is this Azimuthal buſineſſe mentioned at all?

Anſw. Becauſe the Reader might ſee, that the Authour of this Treatiſe was not ignorant of it: yet it is mentioned alſo that if any delight in ſuch a curioſity he may to his liking effect it.

☞ And for a full concluſion note, that, All the former Dials may be made in a Craticular way.

FINIS.

AN INDEX Of the Chief PARTICULARS:

Of the Elliptical Diall with an Index ſtanding in the Zenith-line.

FINIS.

Courteous Reader, be pleaſed to take notice of these Books following, which are very uſefull and neceſſary for all Merchants, Tradeſmen, Accomptants, they are ſold by Nicholas Bourn *at the South entrance of the* Royall Exchange.

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